MILL SECTION of
Concrete

Vol. 38 Chicago, March, 1931 No. 3

New Mexican Cement Plant Serves West Coast Territory

One Rotary Kiln Installed at Hermosillo, With Provision for Future Expanion—Present Capacity 500 Barrels Daily—Unlimited Clay and Limestone Deposits

A NEW, wet-process portland cement manufacturing plant in Mexico, located near Hermosillo, in the state of Sonora, is approaching completion and is expected to start production in the early part of March.

The building of this project by Cemento Portland Nacional, S. A., is considered as the forerunner of extensive quantities of concrete construction work along the west coast of Mexico.

Located to Serve West Coast

Hermosillo, lying about 80 miles inland from the Gulf of California, on the Rio Sonora and on the west coast line of the Southern Pacific Railway of Mexico, is well located for serving the west coast territory.

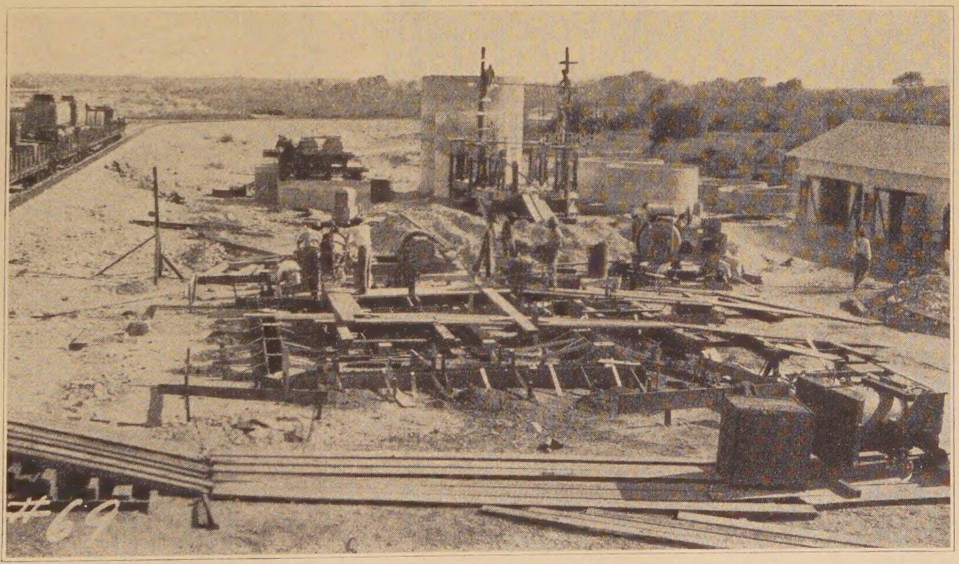
Plant Layout and Capacity

The plant layout is illustrated in the full-page line drawing shown on the next page. From this layout and the halftone illustrations it will be seen that the present installation is small in comparison with portland cement manufacturing plants in the United States.

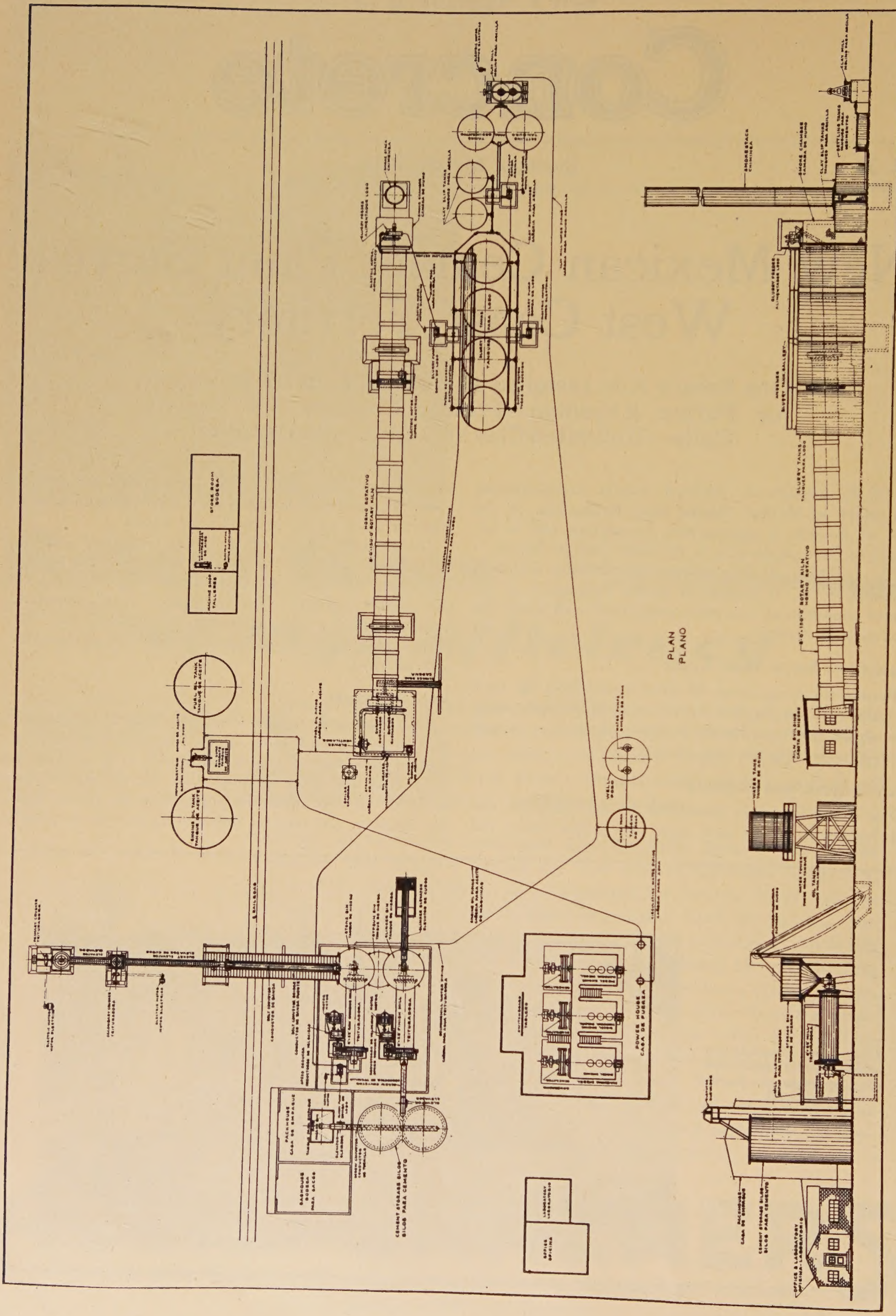
The capacity of the plant as now installed is about 500 barrels daily. This is believed to be adequate to take care of the demand in the early stages of development of this market territory. The installation is so arranged, however, that the capacity may be increased in any department without interrupting the production of the units now installed.

Raw Materials

The plant will utilize limestone from a deposit extending for several miles along the banks of the Rio Sonora, the starting quarry being only a few hundred yards from the plant location. Clay for the mix is also available in large quantities adjacent to the plant. Both the limestone and the clay deposits are present in quanti-



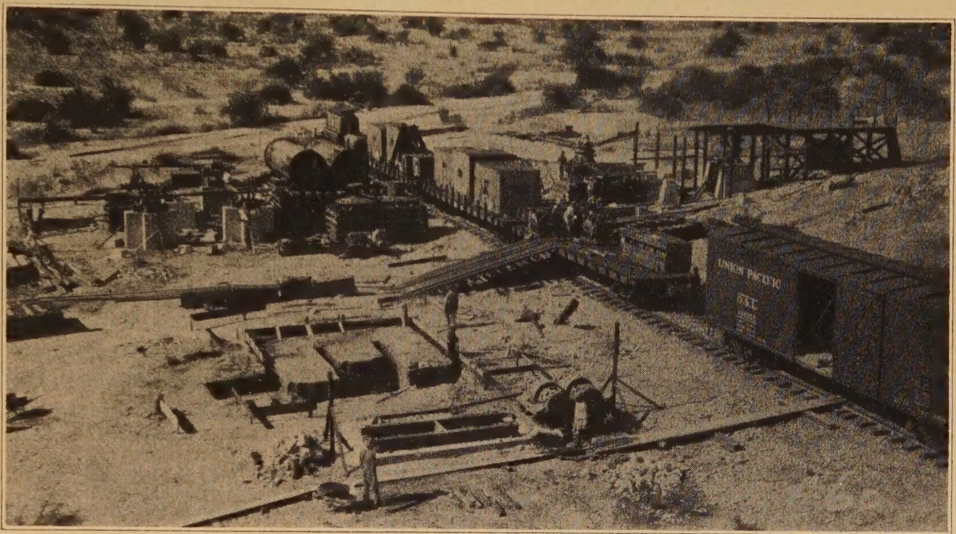
Concreting foundation work. Slurry tanks and clay tanks in the background



Layout of cement manufacturing plant of Cemento Portland Nacional, S. A., at Hermosillo, Mexico ties that, for all practical purposes, are inexhaustible.

Power for operating the drills in the limestone quarry is to be supplied by portable air compressors. So long as the quarry operations are only a short distance from the plant, the limestone will be transported to the crusher by means of motor trucks.

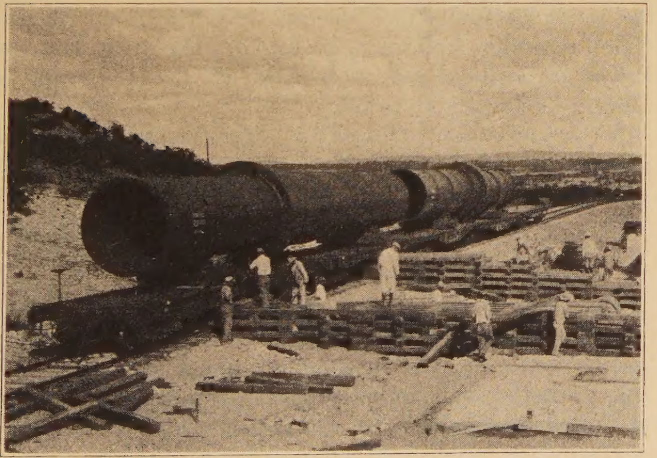
The clay will be excavated with a portable dragline outfit, and will likewise be transported to the plant by motor trucks so long as the distance is not great. A 30-day supply of clay is to be kept in an open-air storage space near the clay mill. This 30-day supply will permit the use of the excavating and hauling equipment at other points around the plant during the greater part of the time.



General view of plant under construction. Crusher foundations at extreme right; left center, grinding mills being installed; in foreground, excavation for kiln firing buildings

The Crushing Plant

The limestone will first be crushed through a 12-inch gyratory crusher, then through a 4½-inch gyratory finishing crusher, both of Traylor manufacture.



Preparing for unloading of 8- by 150-ft. rotary kiln

The 12-inch gyratory crusher reduces the stone to ring sizes ranging from 1¾ to 2¾ inches, while the 4½-inch gyratory finishing crusher produces sizes ranging from ½ to 1 inch.

From the finishing crusher the stone will either be conveyed to the mill feed bin or placed in storage. Mechanical arrangements have also been made so that crushed stone from either the primary crusher or the finishing crusher can be loaded to railroad cars and shipped as commercial crushed stone.

Raw Grinding by Two-Compartment Mill

The raw grinding will be done by a 6-ft. by 22-ft. two-compartment mill, also of Traylor manufacture. The coarse compartment of the mill takes its feed direct from the finishing crusher. The mill discharges into a pump, which pumps the slurry to any one of the four concrete slurry tanks. The agitation in the slurry tanks is maintained by compressed air. Two pumps installed in the slurry tanks then transfer the slurry to the kiln feeder.

Rotary Kiln Is 150 Ft. Long

The rotary kiln now installed is 8 by 150 ft. in size. It will discharge into a drag conveyor installed so as to deliver the clinker over a concrete retaining wall, where it will be stored or delivered to the finish mill bin by a caterpillar crane equipped with a clamshell bucket. This same crane will load the gypsum bin.

Grinding the Clinker

The clinker and the gypsum will be fed to a 6 by 22-ft. compartment finish mill by a rotating table feeder. The finished cement will then be delivered to the concrete storage silos by a screw conveyor and delivered from there to the packer bin by a bucket elevator. Immediate expansion is contemplated in this department, provision having already been made for the installation of Fuller-Kinyon cement pumps.

Packing will be done with a Bates two-tube packer, and provision is made for delivery of the sacked cement to storage, to freight cars or to motor trucks.

Power Equipment

Three 360-h.p. Diesel engines direct-connected to Westinghouse generators will supply all the power for the plant. Electric motors used in driving the various units of equipment are all direct-connected.

Acknowledgments

The Traylor Engineering and Manufacturing Company, of Allentown, Pennsylvania, supplied the major portion of the cement manufacturing and stone crushing equipment, such as the crushers, the stone elevators, the compartment mills in both the raw and finish departments, the rotary kiln, and the feeders.

The plant was designed by the San Francisco office of the Macdonald Engineering Company of California, and all construction work and machinery installations were handled by this company's construction forces at Hermosillo.

U. S. Court Removes Restrictions on Bag-Filling Machine Users

According to an announcement from the U. S. Department of Justice, a consent decree was entered on January 20 in the case of the United States vs. Bates Valve Bag Corporation and the St. Regis Paper Company, under the Clayton and Sherman anti-trust acts, by the U. S. District Court at Wilmington, Del.

The suit charged that the defendants required users of bag-filling machinery leased from them to confine their purchase of bags to those manufactured by the defendants or to suffer the right to use the machines.

A perpetual injunction against the enforcement of the restriction on bag purchasers as to source from which they may supply their needs for bags was entered. Filling machine users are also given the right to fill bags with the machines obtained from the Bates company regardless of the source of the bags.

Consolidated Refinancing Plan Suspended by Action of Stockholder

The Consolidated Cement Corporation is reported to have been enjoined by a stockholder from proceeding with a refinancing plan said to have been proposed by two members of the board of directors for meeting a million dollar obligation.

Wm. D. Pratt, Fredonia, Kansas, owner of stock worth $300,000, in his application, is understood to claim that the action is not to the interest of the corporation.

Mississippi Portland Drops Plans For $1,500,000 Plant

The Mississippi Portland Cement Company, until recently considering the construction of a $1,500,000 cement plant at either Jackson or Macon, Mississippi, is reported to have dropped its plans for the present.

Its office is located in the Canal Bank Building, New Orleans, Louisiana.

Construction Encouraging, Riverside Plant Runs at Capacity

Basing resumption of full capacity operation on projected federal, state and municipal building in California, the Riverside Portland Cement Company plant, near Riverside, reopened on January 15. It had been operating under a curtailed plan for some time.

Missouri Portland Heeds Unemployment; Opens Two Months Earlier

Three hundred men returned to work at the St. Louis plant of the Missouri Portland Cement Company on February 1st. It had originally been planned to reopen April 1st, but due to unemployment, operations were resumed at that time. The management plans to continue operation throughout the year, according to H. L. Block, president.

The men returned to work are equivalent to 71 per cent of the normal number, and the remaining 29 per cent will return April 1.

Superior Portland Share Earns 75 Cents in 1930

Superior Portland Cement, Incorporated, Seattle, Washington, for the year ended December 31, after allowance for the plan of retiring class "A" stock through purchase in the open market, shows net profits of $56,000. This is equivalent to 75 cents a share on 76,145 shares of class "A" stock outstanding at the close of the year.

These earnings compare with $345,000 earned after all charges in 1929, or $4.49 a share on the 76,733 class "A" shares then outstanding.

Louisiana Awards 7,500,000-Barrel Cement Contracts for Highway Work

The state of Louisiana in January awarded contracts for cement for its 1931 paving program, distributing them among eight companies' plants in and about the state.

The contracts were proportioned as follows, in barrels: Lone Star Portland Cement Company, Louisiana, 2,500,000; Oklahoma company, 900,000; Arkansas, 900,000; Trinity, 1,200,000; Marquette, 750,000; Universal Atlas, 500,000; Lehigh, 500,000, and Signal Mountain, 250,000.

Power Engineering Conference Held at Chicago

The fifth Midwest Power Engineering Conference and the fourth National Fuels Meeting were held at the Stevens Hotel, Chicago, February 10 to 13. The fifth Midwest Power Exposition was also held at the Coliseum at Chicago, February 10 to 14.

A comprehensive program covering numerous phases of power generation, distribution and use was scheduled.

Bay City Plant Installs Slurry Filter System

The Bay City, Michigan, plant of the Aetna Portland Cement Company closed down February 15 for general repairs and to permit the hooking up of the new Oliver slurry filter system, recently installed under the direction of Fred L. Boland.

New Castle Plant Installing Separating Machinery

Work on the installation of a complete, new separating unit at the New Castle, Pennsylvania, plant of the Lehigh Portland Cement Company, began late in January, in preparation for early resumption of operation.

Chemical Reactions in the Setting of Cement

Determining State of Combination of Water and Lime Evolved on Hydrolysis — Their Significance — Test Methods and Preparation of Test Samples

By LINCOLN T. WORK[1] and FRANKLIN P. LASSETER[2]

This is the first of three installments of an original treatise describing a comprehensive investigation of the chemical reactions that take place during the setting and hardening of portland cement.

The investigation, made at Columbia University, New York, is the first in a program of research undertaken in the belief that we need a more thorough knowledge about the major compounds in cement. It is with pleasure that we give publication to this important contribution to such knowledge.—The Editors.

Acknowledgment.—Grateful acknowledgment is made to Dr. Samuel Goldschmidt, the donor of the Fellowship in Columbia University, which Mr. Lasseter held during the greater part of this investigation; to Dr. R. H. Bogue, Director of the Portland Cement Association Fellowship at the Bureau of Standards, for his kindness in furnishing the samples of the pure compounds used; to Prof. D. A. Abrams, Director of Research of the International Cement Corporation, for help and for kind assistance in furnishing the commercial cement samples; and to Professor A. H. Beyer and Professor W. J. Krefeld for permitting use of the Testing Laboratory at Columbia University in making some of the test specimens.

ABSTRACT

Methods for the determination of the state of combination of water in a set cement and for the lime evolved on hydrolysis have been tested to determine their significance. In studying the state of combination of the water, the following methods were tested: 1. Extraction with absolute alcohol. 2. Distillation using benzol, toluol and xylol. 3. Vacuum drying. 4. Oven drying in dry air at 90, 105 and 130 deg. C. The test of oven drying at 105 deg. C. was chosen as standard, although it is probably a little low for the true value of uncombined water. Total water was determined at 850 deg. C. Under those conditions a small amount of moisture will remain, but calcium sulfate should not be decomposed appreciably. Therefore, the difference representing combined water should be essentially correct. The ammonium acetate method for lime in clinker has been adapted to measure hydrated lime in a set cement.

A series of samples was prepared with varying water-cement ratios using each of the compounds tricalcium aluminate, tricalcium silicate, and β-dicalcium silicate, and four commercial cements. They were studied to ascertain the nature of the chemical reactions and the rate of hydration and hydrolysis during setting and hardening.

In this study of the properties of the pure compounds, earlier work was checked which showed that tricalcium aluminate hydrates to $3CaO.Al_2O_3.6H_2O$ and this on calcination yields lime and an apparent residue of $5CaO.3Al_2O_3$. It was shown that this hexahydrate can be partially dehydrated in vacuum at 240-250 deg. C. It was also noted that with water-cement ratios of 0.5 and greater the tricalcium aluminate was practically completely hydrated to hexahydrate in 28 days. It is known that tricalcium silicate reacts both by hydration and hydrolysis. It was shown further that during the early stages of hydrolysis approximately one molecule of water combines with the silicate for each molecule of lime liberated. The beta dicalcium silicate was shown to react chiefly by the addition of water and released very little lime for several months.

The pure compounds and cements yielded a typical curve for the percentage of combined water against water-cement ratio. Starting at the origin, the values of combined water rose with water-cement ratio up to a ratio of 0.2 to 0.4 after which they became practically horizontal. In the case of the aluminate, reaction at low water-cement ratio consumed all of the water, but that was not found to be the case with the other pure compounds or with the cements. Hydration was rapid with the aluminate, slower with the tricalcium silicate and very much slower with the dicalcium silicate. The rise of each of these curves with time showed that difference. Tricalcium aluminate yielded no lime in setting. Tricalcium silicate yielded lime more or less similar in amount to the combined water value and the beta dicalcium silicate yielded but small quantities of lime up to three months.

The combined water values for the cements were similar to those for tricalcium silicate but the rate of hydration varied with fineness, early hydration being greater with the finer cements. The lime values were somewhat similar, save for a dip in the curve at low water-cement ratios which appears to be due to selective hydration of the aluminate.

A comparison of the hydration and hydrolysis of the cements was made with the strength of a standard concrete using the same cements at a water-cement ratio of 0.55.

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[1] Assistant professor of chemical engineering, Columbia University, New York.

[2] Graduate student, Department of Chemical Engineering, Columbia University.

The fine cements reacted more completely in the early stages and developed high strength. The coarse cement reacted slowly at first but for a longer time. The later reaction did not develop an equivalent strength. It would therefore appear that after 28 days to 3 months the development of strength is attributable to crystallization rather than to chemical reaction of clinker.

INTRODUCTION

Most of the research being done on portland cement at the present time is intended to improve its physical properties without special regard to the nature of the chemical reactions which take place when the material is mixed with water. The practical reasons for this are obvious, as these are the properties which are directly used. In the belief that further progress will depend upon a more thorough knowledge of the chemical reactions of the major compounds in portland cement, a program of research has been laid down, of which this paper is the first contribution.

The broad purpose of this investigation is to study the chemical reactions in the setting and hardening of cement. To accomplish this objective it was found necessary to study the methods for measuring the state of combination of water in a set cement, and to adapt a method for the determination of the free lime in a cement clinker to the measurement of hydrated lime in a set cement. After these methods were evaluated, those selected were then applicable for testing the reactions of the three pure compounds said to be the constituents of cement, and for the testing of portland cement.

Such an investigation necessitates the limitation of many variables with the study of a few which seem of major importance. For example, the variables of water-cement ratio, the time of aging and fineness are of such primary importance as to warrant a study of the manner of their variation. Other variables, some of which are equally important, as the composition of cement, temperature of curing, moisture condition in curing, and freedom from carbon dioxide, are fixed for this investigation.

The results so secured are intended to show the trend in the hydrating characteristics of cement with respect to the variables studied. To meet the practical requirements as to their bearing upon the behavior of concrete, the results obtained under ideal conditions in the laboratory are compared with the strength data obtained on test specimens of concrete prepared separately.

PERFECTION OF TEST METHODS

In order to measure the extent of hydration and hydrolysis, the following tests have been investigated:

1. State of combination of water.
   a. As combined water.
   b. As moisture.
2. Lime developed on hydrolysis.

State of Combination of Water

The total water in a cement may be determined by igniting the cement at a suitable temperature. There are, however, certain factors which complicate the selection of the correct temperature. It must be sufficiently high to drive off practically all the water. When such a temperature is reached, carbon dioxide is also evolved if present, and consequently the cements under test must be aged in an atmosphere containing essentially no carbon dioxide. Small amounts of water may remain in the cement if it is not actually heated to sintering. If it is heated to sintering, the gypsum which is present may evolve sulphur trioxide, thus making the total loss greater than the total water. A temperature of 850 deg. C. was selected as ignition temperature with the knowledge that the results would be essentially correct for all cements.

The problem of moment is therefore to divide the total water into that which is loosely held and that more permanently combined. Heretofore, oven drying at a temperature around the boiling point of water has been considered the dividing line. Thus, water evolved in the oven at 105 deg. C. might be called "moisture," while that retained at 105 deg. C. but lost on ignition might be called "combined water." The distinction is complicated by the possibility of appreciable surface moisture being retained well above this temperature, of reaction taking place during heating, and even of loosely bonded compounds being dehydrated below this temperature. As McMillan's data[1] shows no sharp break in loss with temperature, some tests were carried out to determine the effect of extracting water at room temperature or of using other media besides air for drying the cement. Four methods for moisture determination were employed:

1. Extraction with absolute alcohol.
2. Distillation using
   a. Benzol.
   b. Toluol.
   c. Xylol.
3. Oven drying in dry air.
4. Vacuum drying at room temperature.

The samples for these tests were made by mixing cement with 30 per cent of its weight of distilled water and allowing it to harden for two weeks. This cement was then ground so that 100 per cent passed through a No. 100 sieve.

In the first method 20 grams of the sample as prepared were ground for two hours in a small pebble mill with 200 cc. of absolute alcohol. The solid material was allowed to settle and the water in the alcohol was ascertained by density determinations.

In the second method, three distilling media were used, benzol with a boiling point of 80-82 deg. C., toluol with a boiling point of 111 deg. C., and xylol with a boiling point of 139 deg. C. In each case 30 grams of the sample were distilled for two hours in 150 cc. of the distilling medium. A reflux condenser was used and the water distilled over collected in a separate receiver where its volume was later measured.[2] From the weight of the sample and the quantity of water obtained the per cent moisture was determined.

For the third method oven tests were made at 90 deg., 105 deg. and 130 deg. C. for comparison with results obtained by the other methods and to determine the effect of different temperatures on the amount of moisture evolved. Losses were ascertained at the end of each hour up to a maximum of four hours. One gram of the sample was in each case weighed into a tared crucible and the losses in weight obtained under the conditions designated.

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[1] F. R. McMillan, *Eng. News Record, 102*, 580-3 (1929).

[2] Bureau of Mines Technical Paper 323A. A. S. T. M. Method D95-23T.

In the vacuum method one gram of the sample was weighed into a pyrex test tube and subjected to 4-10 mm. of mercury for two hours at room temperature.

The following table gives the data obtained by the four methods used.

TABLE I—COMPARISON OF MOISTURE TESTS

Per Cent Based on Ignited Weight of Sample

Method	Time in Hours	Weight in Grams	Per Cent Moisture 90° C.	105° C.	130° C.
Oven drying	1	1.00	12.94	14.61	16.37
	2		13.05	15.34	16.97
	3		13.14	15.59	17.48
	4		13.16	15.60	17.50
Absolute alcohol	2	20.00	14.80—room temperature		
			Benzol 80-82° C.	Toluol 111° C.	Xylol 139° C.
Distillation	2	30.00	16.97	17.63	18.02
Vacuum	2	1.00	9.17—room temperature		

In both the oven drying and the distillation methods, the percentage of moisture increases with increase in temperature of test. The differences are less pronounced and the totals are higher with the distillation method. It would appear that this method more nearly eliminates the effect of equilibrium moisture. On the other hand, the alcohol extraction would eliminate decomposition or further hydration from elevation of temperature during test and its value is below that of moisture at 105 deg. C. With the exception of the vacuum test, which is obviously low, the other values differ by little more than 2 per cent from a mean value of 16.

In the complete removal of water from a cement a proper selection of temperature is important. Thorvaldsen and Grace[3] have shown that after ignition at 850 deg. C. 1.2 per cent water may remain in tricalcium aluminate. In the present investigation some experiments were made with a set cement to determine the effect of varying the temperature of ignition. A standard portland cement was mixed with 35 per cent by weight of distilled water and allowed to harden for one month. The sample was ground so that 100 per cent passed through a No. 100 sieve and was dried at 105 deg. C. The material was then ignited in platinum at 700, 850 and 1,000 deg. C., with results as given in Table II.

TABLE II—IGNITION LOSS WITH TEMPERATURE

Per Cent Based on Weight of Sample Ignited at 1000 Deg. C.

Weight of Sample in Grams	Ignition Temperature in Degrees Centigrade	Per Cent Loss
1.50	700	29.96
1.50	850	30.91
1.50	1000	31.37

Since the "combined water," or that between the two temperatures is of the greatest significance in this study, the correctness of the interval rather than the correctness of the individual result is of the greater importance. Consequently, the conditions for the determination of "free water" or "combined water" for this investigation are according to these specifications:

1. *Free water—moisture.* Weigh one gram into a porcelain crucible, and dry in the oven for three hours at 105 deg. C. with the slow passage of a stream of dry carbon dioxide-free air over the crucible.
2. *Combined water.* Ignite a sample from oven-drying test to constant weight at 850 deg. C.

In general the percentages are calculated on the ignited weight of solid rather than the original weight of the sample, "moisture" being (loss in weight to 105 deg. C.) divided by (ignited weight of cement); and "combined water" being (loss in weight 105 deg.-850 deg. C.) divided by (ignited weight of cement).

With these tests the procedure is simple, and the values are comparable with those of other investigators.

Determination of Lime as $Ca(OH)_2$ in a Set Cement

In order to follow more closely the chemistry of the setting and hardening reactions, the ammonium acetate method of Lerch and Bogue[4] for quicklime in clinker has been adapted to the determination of hydrated lime in a hydrated and hydrolyzed cement. The modified method is given here.

The hydrated and hydrolyzed cement is ground so that 100 per cent will pass through a No. 100 sieve and then dried to approximately constant weight at 105 deg. C. Two- to four-tenths of a gram is weighed into an Erlenmeyer flask containing 60 cc. of a glycerol-absolute alcohol solution. The smaller weight of sample is used as a relatively large quantity of hydrated lime is formed in the samples of high water-cement ratio. The solution is made as outlined by Lerch and Bogue. A one-tenth normal solution of ammonium acetate in absolute alcohol is used. In this work it was standardized by titrating against pure, freshly prepared CaO and also $Ca(OH)_2$ formed by hydrating a weighed quantity of CaO. The reaction is slower with the latter, but the results are accurate. The equation follows:

$$Ca(OH)_2 + 2NH_4COOCH_3 \rightarrow Ca(COOCH_3)_2 + 2NH_3 + 2H_2O$$

Small pieces of porous tile should be placed in the flask to prevent bumping. A water condenser with a total length of eight inches is used for reflux to prevent loss of alcohol. This is inserted into the neck of the flask. Above the condenser is placed a burette containing the ammonium acetate solution. The apparatus is mounted so that the condenser is vertical. This permits addition of the ammonium acetate directly through the condenser into the solution containing the lime to be titrated. The solution is boiled and titrations are made as rapidly as the lime is dissolved. The reaction is considered complete when no pink color appears after boiling for one hour. The lime content of the sample is then calculated from the known CaO equivalent of the ammonium acetate. A sketch of the apparatus is shown in Figure 1. With this arrangement it is not necessary to remove the condenser for each titration, loss of alcohol is less, and the test is shortened by making possible the titration of the lime as rapidly as it is dissolved. As many as a dozen titrations may be conveniently carried out simultaneously. The results obtained are reported in general as per cent CaO based on the ignited weight of sample.

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[3] T. Thorvaldsen and N. S. Grace, *Canadian J. Research*, *1*, 36-47 (1929).

[4] Wm. Lerch and R. H. Bogue, *Ind. Eng. Chem.*, *18*, 730 (1926). (Modification of method described in reference cited communicated privately.)

Efforts have been made by several investigators to determine lime evolved on hydrolysis of a cement. Since the Bogue and Lerch method is applicable to the determination of CaO, the pure compounds and cements have been calcined. Direct determination of $Ca(OH)_2$ has been limited by the slow rate of reaction of the hydrate and by the chances of error in having water present. On the other hand, calcination has failed to give proper lime values due to the decomposition of aluminate and due to hydration by steaming during calcination. To determine whether it was feasible to test the cement as hydrated and without calcination, tests were made with tricalcium aluminate, beta dicalcium silicate, and tricalcium silicate. Two grams of each compound were mixed with 50 per cent by weight of distilled water. The tricalcium aluminate and tricalcium silicate were allowed to set for 24 hours, and the beta dicalcium silicate was allowed to set for seven days. Hydrated samples of each were ground so that 100 per cent passed through a No. 100 sieve. A four-tenths gram sample of each was used and the hydrated lime determined in duplicate by the method described above. The remainder of each sample was ignited and the lime determined in the same way. Results of tests are listed in Table III.

TABLE III—LIME EVOLUTION FROM PURE COMPOUNDS

Per Cent Based on Ignited Weight of Sample

Compound	Treatment	Ignition Temp. ° C.	Per Cent CaO
$3CaO.Al_2O_3$	Unignited		0.00
"	"		0.00
"	Ignited	600–650	25.58
"	"	850	9.99
$2CaO.SiO_2$	Unignited		0.24
"	Ignited	850	0.22
$3CaO.SiO_2$	Unignited		10.00
"	"		10.20
"	Ignited	850	9.50
"	"	850	9.40

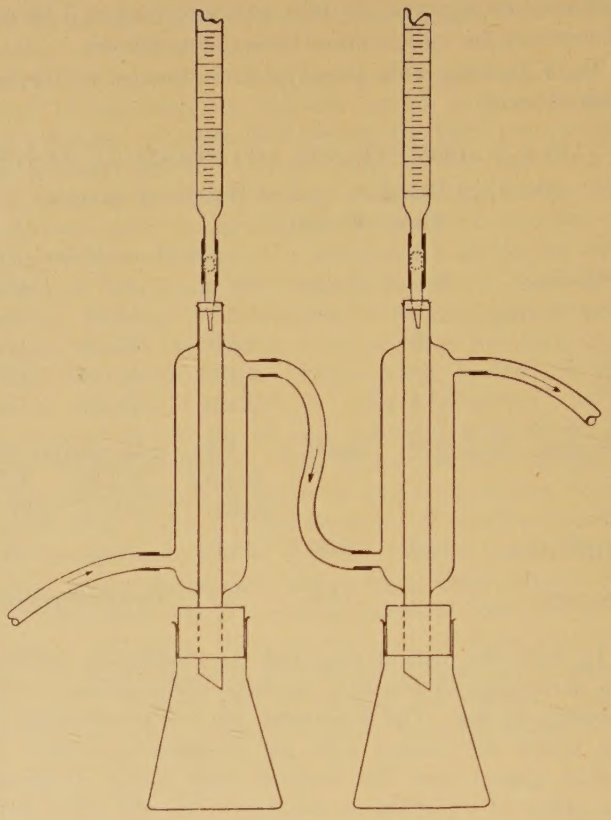
Data obtained with the tricalcium aluminate confirmed the results found by Lerch and Bogue[5] and Thorvaldsen and Grace[3] that the compound hydrates on addition of water but does not hydrolyze, and that above 600 deg. C. the hydrate breaks down, liberating lime. It is to be observed that the amount of lime liberated by the hydrated tricalcium aluminate depends upon the temperature of ignition, recombination taking place at higher temperatures. The 25.6 per cent of lime liberated on calcination of aluminate at 600-650 deg. C. is approximately the quantity liberated when the compound reacts as follows:

$$3(3CaO.Al_2O_3.6H_2O) \rightarrow 5CaO.3Al_2O_3 + 4CaO + 18H_2O$$

The reaction represents the liberation of 27.67 per cent lime.

Ignition did not seem to affect the lime content of the beta dicalcium silicate which was low in the hydrated sample.

FIG. 1



Apparatus for Lime Test

With the tricalcium silicate there was no material change in lime content after ignition. The small reduction in lime which was noted may be due to recombination.

In order to test the method further the tricalcium silicate was mixed with varying percentages of water. Each sample was molded at a given pressure and allowed to set for 24 hours. The samples were ground so that 100 per cent passed through a No. 100 sieve and were dried at 105 deg. C. The hydrated lime in the unignited sample and the lime in the ignited material were determined. The titrations were made as rapidly as the solution of the lime would allow and readings taken at definite time intervals. The results are given as cubic centimeters of ammonium acetate solution used at the end of each time interval (Table IV).

The data in Table IV show that the rate of the reaction was more rapid with the lime in the ignited material than with the hydrated lime in the unignited material.

An additional series of tests were made on the same samples after they had set for six months. Equal weights of each sample calculated as ignited material were used for the tests (Table V).

Data in Table V show the same general tendency as that in Table IV. The lime in the ignited sample reacted more rapidly than the hydrated lime in the unignited sample.

The final percentages of lime in both the unignited and the ignited samples for the 24-hour and the six-month data as given in Tables IV and V are listed in Table VI.

In the 24-hour samples, ignition gave higher lime values at low water-silicate ratios. It is suggestive of hydration by steaming during ignition. When more than 16 per cent water was used in mixing, the ignited and unignited samples gave similar results. In the six-months' tests, ignited and unignited samples gave similar results at low

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[5] Wm. Lerch and R. H. Bogue; private communication.

[3] Loc. cit.

TABLE IV—TIME-RATE OF TITRATION OF LIME IN TRICALCIUM SILICATE

Water-Cement Ratios Varied—Time of Set 24 hours.

Time	Number 1		Number 2		Number 3		Number 4		Number 5		Number 6		Number 7		Number 8	
	6% H_2O		11% H_2O		13% H_2O		16% H_2O		33.3% H_2O		45% H_2O		60% H_2O		100% H_2O	
in	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.
	.3631g	.3633g	.3630g	.3634g	.3624g	.3627g	.3614g	.3614g	.3631g	.3631g	.3631g	.3627g	.3626g	.3630g	.3614g	.3630g
Minutes	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
20	......	1.50	......	1.85	......	2.25	......	2.15	......	2.40	......	2.35	......	2.05	......	2.65
30	0.20	......	0.50	......	0.70	......	0.70	......	0.45	......	0.30	......	0.20	......	0.20	......
40	......	2.30	......	2.65	......	2.85	......	2.90	......	2.80	......	2.40	......	2.20	......	2.80
50	0.35	......	0.80	......	1.25	......	1.40	......	0.75	2.80	0.55	2.40	0.50	2.20	0.45	2.80
70	0.40	2.50	1.00	2.65	1.55	2.85	1.80	2.90	1.00	......	0.70	......	0.70	......	0.50	......
120	0.55	2.50	1.25	2.65	1.90	2.85	2.05	2.90	1.30	......	1.00	......	0.95	......	0.85	......
160	0.65	......	1.45	......	2.10	......	2.35	......	1.65	......	1.40	......	1.35	......	1.10	......
210	0.85	......	1.70	......	2.20	......	2.50	......	1.85	......	1.70	......	1.65	......	1.45	......
265	0.90	......	1.75	......	2.30	......	2.60	......	2.15	......	2.05	......	2.05	......	1.80	......
325	0.90	......	1.75	......	2.30	......	2.60	......	2.35	......	2.25	......	2.15	......	2.25	......
385	......	......	......	......	......	......	......	......	2.45	......	2.50	......	2.20	......	2.55	......
445	0.90	2.50	1.75	2.65	2.30	2.85	2.60	2.90	2.55	2.80	2.60	2.40	2.30	2.20	2.80	2.80

TABLE V—TIME-RATE OF TITRATION OF TRICALCIUM SILICATE

Water-Cement Ratios Varied—Time of Set 6 Months

Time	Number 1		Number 2		Number 3		Number 4		Number 5		Number 6		Number 7		Number 8	
	6% H_2O		11% H_2O		13% H_2O		16% H_2O		33.3% H_2O		45% H_2O		60% H_2O		100% H_2O	
in	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.	Hyd.	Ign.
	.3338g	.3358g	.3326g	.3326g	.3290g	.3290g	.3242g	.3242g	.3007g	.3007g	.2967g	.2967g	.2932g	.2932g	.2894g	.2894g
Minutes	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
10	......	2.25	......	3.35	......	4.05	......	4.75	......	5.30	......	7.10	......	7.20	......	7.35
20	0.10	3.80	0.30	4.70	0.60	5.45	0.80	6.05	3.00	7.50	5.90	7.45	5.95	9.30	5.95	10.65
50	0.20	4.50	0.80	5.10	1.20	5.70	1.55	6.30	5.10	7.65	8.20	8.70	8.45	9.40	9.90	10.75
90	0.30	4.60	1.50	5.20	2.15	5.95	2.45	6.40	7.30	7.75	9.95	8.90	11.35	9.60	12.65	10.85
140	0.40	4.60	2.15	5.20	3.05	5.95	3.55	6.40	8.45	7.85	10.80	9.10	12.00	9.70	13.65	10.95
200	0.60	......	2.75	......	3.90	......	4.30	......	9.05	7.85	11.10	9.10	12.10	9.70	13.90	10.95
260	0.70	......	3.15	......	4.45	......	4.75	......	9.30	......	11.20	......	12.20	......	14.05	......
320	0.90	......	3.60	......	4.95	......	5.25	......	9.55	......	11.45	......	12.30	......	14.20	......
380	1.30	......	4.25	......	5.45	......	5.75	......	9.85	......	11.55	......	12.40	......	14.30	......
440	1.60	......	4.60	......	5.80	......	6.15	......	10.00	......	11.70	......	12.50	......	14.40	......
500	1.90	......	4.90	......	6.00	......	6.36	......	10.15	......	11.80	......	12.60	......	14.50	......
560	2.30	......	5.10	......	6.00	......	6.40	......	10.20	......	11.90	......	12.70	......	14.50	......
620	2.70	......	5.20	......	6.00	......	6.40	......	10.20	......	12.00	......	12.80	......	14.50	......
680	3.10	......	5.20	......	6.00	......	6.40	......	10.20	......	12.10	......	12.90	......	14.50	......
740	3.40	......	......	......	......	......	......	......	10.20	......	12.10	......	12.90	......	14.50	......
800	3.70	......	......	......	......	......	......	......								
860	4.00	......	......	......	......	......	......	......								
920	4.30	......	......	......	......	......	......	......								
980	4.40	......	......	......	......	......	......	......								
1040	4.40	4.60	5.20	5.20	6.00	5.95	6.40	6.40								

water-silicate ratios, while at the higher water-silicate ratios, the ignited samples showed much lower lime values. It seems reasonable to assume that unignited material is more representative of true lime content than ignited. Further, ignition gives obviously inaccurate lime values with cement; and so the test was made directly without ignition to obtain a trend as to the lime formation in the hydrolysis of the pure compounds and of cement.

Preparation of Test Samples

In the experiments outlined in the next two sections the following compounds and commercial cements were used as test samples.

1. Tricalcium Aluminate.
2. Tricalcium Silicate.
3. Beta Dicalcium Silicate.
4. Three cements said to have been from the same clinker, as follows:
    a. Cement A—51.8% passing a 200 sieve.
    b. Cement B—82.7% passing a 200 sieve.
    c. Cement C—98.8% passing a 200 sieve.
5. Cement D—A high early strength cement.

A series of eight samples of each material was prepared. Samples 1 to 4 were molded under pressures of 100,000, 30,000, 10,000, and 3,000 pounds per square inch, respectively. Enough distilled water was added in each case to leave a slight excess on the ends of the specimen which was absorbed after the pressure was released, and the amount of water added was listed in the tables as the water-cement ratio. Samples 5 to 8, inclusive, were molded at atmospheric pressure with the water-cement ratios given. All samples were stored in tightly closed bottles to avoid uncontrolled reaction with carbon dioxide. There was an excess of water to give saturation. The samples were stored in a thermostat bath at 25 deg. C.

TABLE VI—TOTAL PER CENT LIME IN 24-HOUR AND 6-MONTH TEST SAMPLES

Treatment	% CaO on Ignited Weight of Sample							
	1	2	3	4	5	6	7	8
24-hour:								
Unign.	3.30	6.51	8.64	9.90	9.60	9.71	8.61	10.98
Ignited	8.80	9.41	10.14	10.32	9.95	8.54	7.82	10.31
6 Mo.:								
Unign.	9.04	10.79	12.58	13.62	23.41	28.14	30.36	30.57
Ignited	9.45	10.79	12.48	13.62	18.01	21.16	22.83	26.11

Tests were made on the different samples as shown in the tables at time intervals of 24 hours, 7 days, 28 days, 3 months and 6 months. Moisture, combined water, and hydrated lime were determined as outlined under test methods.

In all these determinations the values have been presented in a standard tabular form. The first column represents the nomenclature of the sample and thus roughly the water-cement ratio. The second column represents the amount of water added. The third column represents the total amount of water lost after calcination. It may be lower than the amount added as some evaporation may take place in the handling of the sample before drying it in the oven; or it may be higher when the samples have been stored a long time and have absorbed moisture from the saturated atmosphere surrounding them. The fourth column, representing "free water," may be low due to slight evaporation in handling the samples. The fifth column representing "combined water" is here considered significant of the hydration of the cement. The sixth is considered significant of the hydrolysis, being the percentage of calcium oxide measured in the form of hydrate. The seventh column represents the amount of water combined with the lime as hydrate; while the eighth column represents the remainder of the "combined water."

All results are given as per cent by weight based on the ignited cement. In plotting the curves total water as originally added was used as abscissa. This value represents conditions under which initial setting took place, while the total water developed on test may deviate from it due to loss or gain of moisture in handling or in storage. There was some possibility of segregation but this was carefully guarded against by proper sampling when making the tests. Single determinations only were made at each point. The errors in individual points were smoothed by the continuity of individual curves and by their relation to each other.

(To be Continued)

Marquette Boat and Barges Make Initial Bulk Cement Trip

The maiden trip of the cement boat and barges of the Marquette Cement Manufacturing Company from the plant at Cape Girardeau, Missouri, to Memphis, Tennessee, was made on January 24.

The bulk cement cargo, 6,000,000 lbs., was reported the largest ever brought to the city. The cement was placed in storage in the company's recently completed silos there.

Five Alpha Plants Reopen Early in February

February 2 marked the reopening of the five Alpha Portland Cement Company plants at Jamesville, New York; Martins Creek, Pennsylvania; St. Louis, Missouri; La Salle, Illinois, and Birmingham, Alabama.

Steady operation for some time to come is looked for.

Page Michigan Taxpayers

A bill to be introduced shortly into the Kansas state legislature by W. H. Ryan, a Girard representative, provides for state manufacture of cement to be used exclusively in highway construction.

The bill provides that not later than May 1 the governor appoint a commission of three men to select a location. The governor is directed to appoint a superintendent before July 1. The state could engage in the manufacture of brick or other road materials, under the terms of the bill.

"Ryan's bill," according to local reports, "prohibits the state entering into competition with private industries, thus overcoming the constitutional provisions which safeguard business interests.

"Ryan believes the state would save millions of dollars in completion of its road system through operation of its own cement plant."

Riverside Report Discloses Strong Financial Position

The Riverside Cement Company, Los Angeles, California, reports net earnings for 1930 of $509,278. These earnings are after charging of $372,120 for depreciation and depletion.

During the year 1930, the company retired 1343 shares of its first preferred stock and has purchased and holds 1907 shares for future retirement. The net amount of shares in the hands of the public at the close of the year was 59,130. Net earnings as reported were equivalent to over 1.4 times the dividend requirement of the first preferred stock in the hands of the public.

The balance sheet shows an exceptionally strong working capital position. Current assets are shown as $2,968,927, of which $1,061,313 is represented by cash. Current liabilities are $229,718. Ratio of current assets to current liabilities is approximately 13 to 1 and net working capital is $2,739,209.

The company expended in 1930 $381,565 in capital investment, completing an extensive program of development, whereby the limestone requirements of its Crestmore plant will be obtained at the plant site.

Penn-Dixie Profits Up; Earns $4.32 on Preferred

The Pennsylvania-Dixie Cement Corporation and its subsidiaries for 1930 show a net profit of $587,461, equal to $4.32 a share on 135,888 shares of 7 per cent preferred, on which no dividends have been paid since September, 1929. This compares with $332,268, or $2.44, paid at that time.

Kinston, North Carolina, Reported as Site of New Plant

The possibility of the location of a $3,000,000 cement plant near Kinston, southeast North Carolina, is reported.

This is farm country, and not far from New Bern, near where four years ago raw materials were being investigated by Michigan interests.

Boston Bans Belgian Cement in Municipal Work

Action banning the use of Belgian cement in municipal improvements was taken recently by Mayor Curley of Boston. As a result, domestic producers in the territory anticipate an end to the profitless selling prevalent for the past three years.

◂ EDITORIAL ▸

Where More Sustained Promotion Is Needed

THERE is one market for portland cement that has immense possibilities, and has in fact been cultivated by individual cement companies; but it seems to us this market has not been promoted with sufficiently co-ordinated or sustained effort by the cement industry as a whole. We refer to the cement requirements in concrete-encased steel frame buildings.

A building of this type has a structural frame of steel, with columns, girders and beams encased or imbedded in concrete. The floor slab is of reinforced concrete. Roughly, it utilizes about 80 per cent of the quantity of cement required in a similar building of out-and-out reinforced concrete construction.

A few specific instances will illustrate the great possibilities lying here. The Merchandise Mart, a building of this type completed in Chicago early in 1930, with 5,800,000 square feet of floor area, required 285,000 barrels of cement. That is equivalent to one barrel of cement to every 20 square feet of floor area—a close approach to what the cement requirements would have been if the structure had been entirely of reinforced concrete.

Buildings of ordinary size tell the same story. For instance, an ordinary tall office building of this structural type now under construction for the Kansas City Power & Light Company will require 11,000 barrels of cement. In Pittsburgh, a 9-story building of quite ordinary size, known as the McCann Store building, utilized about 3,000 barrels of cement in the foundations and in 100,000 concrete units employed as column fireproofing and in the walls and partitions.

It is unfortunate that the building material association representing the structural steel industry is not friendly toward concrete for fireproofing steel frames, or for use in structural combination with steel. On the contrary, that association is vigorously promoting clay brick and tile fireproofing for steel members, along with tile-arch floor construction, a type which requires very little concrete above the foundation walls.

In contrast, some of the smaller associations representing steel specialties are actively promoting the concrete-encased steel frame building, because of the market possibilities for their own products.

The attitude of the organization representing the steel industry need not deter the cement industry and its allies from promoting, just as vigorously, the concrete-encased steel frame type.

Much work will be required in the education of architects and structural engineers, to the end that all will learn what a few of the more progressive ones have learned for themselves—namely, that the concrete-encased steel frame building is more economical than any other fireproofed steel frame type if full recognition can be given to the combined strength of both the concrete and the steel. This means that nearly every city building code must be amended, for practically all such regulations require the structural steel to be figured to carry the entire load, the concrete being considered only as fireproofing. The amending of city building codes is in itself a long-drawn-out problem, well punctuated with discouragements.

In another direction, the development of lightweight aggregates will accomplish much toward reducing the dead weight, and consequently the steel tonnage and the cost, of a concrete-encased steel frame building.

While much has already been accomplished, the successful promotion of this type of building can be realized only through well formulated plans and sustained effort, properly co-ordinated, by all the material associations whose industry has something to gain by the more complete development of this market. The vast potential market is well worth that effort and all that the effort will cost.

Long Kilns—and Other Installations

RECENTLY a single letter brought the news that three cement plants were installing long rotary kilns to replace older and shorter ones. In one plant a 406-foot kiln is to replace four of those at present in use.

If the one long kiln comes up to expectations it will require less fuel per barrel of cement than the old kilns required. It will not only do the work of the four old ones, but will do it better. It will be possible, in this long kiln, to produce a clinker of complete chemical combination, which means that it will have a high content of tricalcium silicate and tricalcium aluminate. That, in turn, will mean a high-early-strength cement. It should be a sound cement, for it should contain but little free lime, since most of the lime will be taken up in the formation of the tricalcium compounds.

The long rotary kiln has other advantages which must, of course, be balanced against the cost of taking down the old kilns and installing the new.

But after all, the fact of greatest significance about these long kiln installations is that replacement installations of such magnitude are being made. Apparently the managers of these plants are determined to manufacture a cement that is second to none, and they are going through with the changes necessary to accomplish this end.

Michigan Manufacturers Demand Closing of State Cement Plant

Claim State Sells at 12-Cent Loss—Deficit Made Up By Taxation—Individual Letters Sent Legislators

In the midst of considering a proposal that the Michigan state cement plant at Chelsea be abandoned or sold after losing $100,000 on 1930 operations, state legislators were deluged recently by letters from a group of Michigan portland cement manufacturers urging that some action be taken.

Included among those who took part in this means of bringing certain facts about the state-operated plant to the attention of each legislator by way of an individual letter were the Newaygo, Peerless and Petoskey Portland Cement companies.

John L. A. Galster, manager and treasurer of the former, wrote as follows, according to the Charlevoix, Michigan, *Courier* of January 21:

"Operation during the year 1930 of the Michigan cement industry, at Chelsea, as an industry of Jackson prison not only cost the taxpayers of Michigan upwards of $100,000, but has added materially to the unemployment situation in the cement industry of the state."

"The cement industry in Michigan," according to Mr. Galster's letter, "has felt the business depression more than the industry in any other state. During the year a great portion of the cement sold in Michigan went into highway construction, and although the state lost in excess of 12 cents a barrel on all cement produced at Chelsea, it sold to the state highway department more than 500,000 barrels.

"In the face of a business depression the cement industry maintained its employment and wage schedules during the last year, to take care of its employees, in some instances thus entailing an actual loss upon each barrel of cement sold. Due to the operations of the state plant, however, the privately owned plants were forced to cease operations early in the fall, and their employees face an enforced lay off.

"The figures used in computing the loss on the operations of the state owned cement plant were based upon an audit report of this industry by Ernst & Ernst. The figures were obtained, using the usual depreciation figures on the plant, the same as are used on privately owned plants, but there was nothing charged against operation for sales costs, taxes, or other similar items, such as privately owned plants must face, nor was there anything charged for the feeding and clothing of the 200 or more prisoners employed at the plant, a charge which is made against Jackson prison."

Mr. Galster says in his letter that "in the fiscal year ending June 30, 1929, there was a deficit of $85,000 in the operation of the plant, that the deficit for the last fiscal year was about as large. He said that the figures show the plant to be operating at a daily loss of more than $350 to the taxpayers, who are paying approximately $1.75 a day for the privilege of working each of the 200 convicts, in addition to the $1.17 per day it costs the state for their keep."

The letter points out that the privately owned cement plants in Michigan represent an investment of $75,000,000 and that these owners, more than 10,000 stockholders, with 5,000 employees, ask that the state stop operations of the Chelsea plant, not only as an economy measure, but as a protection to the industry and its employees.

Lehigh Declares Dividend; Wall Street Journal Reports Good Position

The Lehigh Portland Cement Company, Allentown, Pennsylvania, has declared the regular quarterly divident of $1.75 on its preferred stock, payable April 1 to stock of record March 14.

Report of the Lehigh Portland Cement Company for the year ended November 30 shows further strengthening of its already good liquid position, according to the *Wall Street Journal*. At the close of its fiscal year on November 30, last, the company's ratio of current assets to current liabilities had advanced to 14.6 to 1 from 9.9 to 1 in 1929 and 8.3 to 1 in 1928, net quick assets reaching the new peak of $17,418,611, an increase of $455,494 for the year.

Of current assets of $18,701,256, cash and government securities totaled $13,411,184, representing increases of $7,298,180 in the latter item and $924,959 in cash. The gains in those accounts reflected the withdrawal of $8,000,000 from the demand loan market, where it was employed during the period of high call money rates in 1929. Another factor contributing to the increase in cash and government securities was the further liquidation of cement inventories by $361,295 to $2,803,192, the lowest figure in many years.

Lehigh last year wrote off its books four of its oldest plants. One was located at Ormrod, Pa., one at Mitchell, Ind., and two at New Castle, Pa. The write-off did not reduce surplus since ample depreciation had been provided over a period of years. Because a reserve for these mills had been fully provided for, the land, buildings, machinery and equipment account was reduced by $2,808,762 and the reserve for depreciation was decreased a like amount.

Regional Safety Meetings at Dallas and Birmingham

The first of the 1931 regional safety meetings sponsored by the Portland Cement Association was held at the Baker Hotel, Dallas, Texas, on January 22.

Another was held at Birmingham, Alabama, on January 27. Both were all-day sessions.

Two Long Kilns Being Installed in Houston Plant of International

Two 400-ft. rotary kilns are being installed at the International Cement Corporation's plant at Houston, Texas, to take the place of shorter kilns previously in service. The new installation is being made by F. L. Smidth & Company, of New York.

Birmingham Plant Reopens After Three-Month Shutdown

The Birmingham, Alabama, plant of the Universal Atlas Cement Company reopened in the middle of January at close to capacity operation, after a three-month shutdown.

Constitution of Portland Cement Studied by X-Ray Method

CaO Up to Two and a Half Per Cent Seldom Found—Amount of Crystalline Phase Necessary to Be Recognized—No Conflict in Interpretation of Three Methods

By L. T. BROWNMILLER and R. H. BOGUE

(Continued from February issue)

Solid Solutions of Aluminates in Silicates

It has been reported that $3CaO.SiO_2$ and $3CaO.Al_2O_3$ are capable of entering into solid solution with each other and that they exist as a solid solution in cement clinker. It is extremely difficult by optical methods to identify positively small amounts of $3CaO.Al_2O_3$ in the presence of $3CaO.SiO_2$. The indices of the two compounds are practically identical, 1.710 for $3CaO.Al_2O_3$ and a mean index of 1.715 for $3CaO.SiO_2$. Moreover, in iron-containing systems, the index of $3CaO.Al_2O_3$ may be raised so that its index may be the same or somewhat higher than that of $3CaO.SiO_2$. And, although $3CaO.SiO_2$ is birefracting, yet its birefraction is so low that in small grains it may not be evident. Because of these difficulties, microscopical examinations have only seldom detected $3CaO.Al_2O_3$ in cements and theories such as solid solution formation have been advanced to explain this failure.

Although optical similarities make the microscopical examination unsatisfactory as a means for the identification of $3CaO.Al_2O_3$ in the presence of $3CaO.SiO_2$, distinct differences in the X-ray diffraction patterns of those two compounds would appear to provide, in the X-ray method, a reliable means for such an identification. If the $3CaO.Al_2O_3$ exists as such in a sintered mixture with $3CaO.SiO_2$ and $2CaO.SiO_2$, the X-ray diffraction pattern of the aluminate will be superimposed upon those of the other two compounds. But if the $3CaO.Al_2O_3$ enters into a solid solution with either of the calcium silicates, the pattern will show the lines of that silicate in a uniformly shifted position with reference to the location they would occupy if the compound were in pure state. Likewise, if either silicate entered into solid solution with the aluminate, the pattern of the aluminate would occupy a shifted position.

To study this problem, a sample of CaO, Al_2O_3, and SiO_2 was mixed to form a composition represented by 47 per cent $3CaO.SiO_2$, 47 per cent $2CaO.SiO_2$ and 6 per cent $3CaO.Al_2O_3$. This sample was burned at 1,500 deg. C., reground and burned at 1,525 deg. C., following which treatment it showed no free lime by White's test. A mechanical mixture of the pure compounds in the proportion 47 per cent $3CaO.SiO_2$, 47 per cent $\beta 2CaO.SiO_2$ and 6 per cent $3CaO.Al_2O_3$ was then made. These two samples were exposed to X-radiation on the same film—hence under exactly the same conditions.

The two patterns, shown in Fig. 2, appear to be identical in every respect, both in the position and in the intensity of the lines. Each of the compounds was definitely identified. Very careful measurement revealed only such slight differences as would obtain by repeated measurements on the same pattern. Several additional comparisons of the same character were made on compositions containing up to 15 per cent of $3CaO.Al_2O_3$, but the results obtained were similar to those just described. This demonstrates that the pattern of none of those compounds is shifted when sintered preparations are obtained in the system $CaO\text{-}Al_2O_3\text{-}SiO_2$ in compositions similar to portland cement clinker. The experiment confirms extensive tests that have been made in this laboratory on commercial and laboratory cements. In a great many of these, tricalcium aluminate has definitely been identified but in none of them has there been observed any shift in the position of the patterns, either of the aluminate or the silicates. The data constitute convincing evidence that solid solutions are not formed between tricalcium aluminate and either tri- or dicalcium silicate in amounts sufficient to be detected by X-ray means.

Free Lime

In a study reported from this laboratory,[10] it was indicated that free CaO does not occur in portland cements in amounts exceeding three per cent and that probably the content is generally less than two per cent. The method used for determining the free CaO was the ammonium acetate method,[11] the results of which were confirmed qualitatively by White's[12] test. Nacken, however, has reported that commercial cements may contain significant amounts of fine-grained CaO as determined by the X-ray method.

Nacken obtained his evidence for the presence of free CaO in cements from pin-hole diffraction patterns. These diagrams consist of a series of concentric circles; identification of a compound is effected by the measurement of the diameters and relative intensities of the lines of the circles.

As a matter of interest, pin-hole photographs were made in this laboratory of a commercial clinker, $3CaO.SiO_2$ and CaO.

The diameters of the circles and relative intensities are recorded in Table V.

An examination of these data shows that there is no similarity between the patterns of CaO and cement clinker while the patterns of $3CaO.SiO_2$ and this particular clinker correspond within the limit of accuracy by this method. No further studies were made with pin-hole diagrams since the method described in this report is a development which gives far superior resolution of the lines from which measurements of greater accuracy may be obtained.

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[10] Wm. Lerch, CONCRETE, C. M. S. 35 (1929), July 109; August 115.

[11] Wm. Lerch and R. H. Bogue. *Ind. Eng. Chem.*, Anal. Ed., 2 (1930), 296.

[12] A. H. White, *ibid.* 1 (1909), 5.

A study was then made of the adaptability of the X-ray method for identifying CaO in cements. A commercial raw mixture was obtained and burned at different temperatures. One portion, burned at 1,435 deg. C., was found, by the ammonium acetate method, to contain 2.8 per cent of free CaO. Another portion, burned at 1,500 deg. C., was found to contain 0.1 per cent of free CaO. The chemical analysis of this clinker and the calculated composition of the clinkers obtained are given in Table VI.

TABLE V

Pin Hole X-ray Data on a Cement Clinker, $3CaO.SiO_2$ and CaO.

Clinker	$3CaO.SiO_2$	CaO
3.73 m	3.70 m	
3.08 ss	4.07 ss	4.05 m
4.35 ss	4.35 s	4.75 ss
4.95 ww	4.95 ww	
5.25 m	5.23 m	
6.03 ww	6.00 ww	
6.67 s	6.65 s	
7.35 m	7.34 w	6.95 s
7.75 w	7.78 w	
8.15 m	8.13 m	
		8.39 m
		8.90 m

TABLE VI

Chemical Analysis and Calculated Compound Composition of a Clinker Burned at 1,435 Deg. C. and 1,500 Deg. C.

Chemical Analysis		Calculated Composition at 1,435 deg. C.		Calculated Composition at 1,500 deg. C.
Oxides	Per Cent	Compounds	Per Cent	Per Cent
CaO	64.7	$3CaO.SiO_2$	26	37
Al_2O_3	5.8	$2CaO.SiO_2$	50	41
Fe_2O_3	2.7	$3CaO.Al_2O_3$	11	11
SiO_2	24.1	$4CaO.Al_2O_3$		
MgO	1.8	Fe_2O_3	8	8
		MgO	1.8	1.8
		CaO	2.8	0.1

Table VII contains the X-ray diffraction data obtained on the two clinkers, together with the interplanar spacings and intensities of the lines for CaO, $3CaO.SiO_2$, $\beta 2CaO.SiO_2$ and $3CaO.Al_2O_3$.

It will be observed that the patterns of the two differently burned samples are not identical. The points of difference lie in the lines which are characteristic of CaO. Lines 17, 23 and 29, which are found to be due to CaO and are not found in the pattern of any of the other compounds, are present in the X-ray pattern of the material burned at 1,435 deg. but are absent in the pattern of the sample burned at 1,500 deg. C. Furthermore, the strength and breadth of line No. 7 and the breadth of line No. 22 from the low burned sample indicate that those lines are due to the strong corresponding lines of CaO rather than to the medium and weak corresponding lines of the $\beta 2CaO.SiO_2$ and $3CaO.SiO_2$ respectively. These data show that the free CaO of the low burned sample can be positively identified by this means.

In Fig. 3 the upper pattern is that of the clinker burned at 1,435 deg. C. which contains 2.8 per cent uncombined CaO. The lower pattern is that of the sample burned nearly free of uncombined CaO at 1,500 deg. C. Two lines show up prominently in the upper pattern that are very weak and absent, respectively, in the lower pattern. These are the lines No. 7 and 17 of Table VII. The other differences, noted on the original film, are not observable on the print.

TABLE VII

Interplanar Spacings of Diffraction Patterns of a Cement Composition Burned at Two Different Temperatures Together with the Interplanar Spacings of the Lines of $3CaO.SiO_2$, $\beta 2CaO.SiO_2$, $3CaO.Al_2O_3$ and CaO which May Be Observed When Those Compounds Are Present in Mixtures Approximating the Composition of Portland Cement Clinker.

Line No.	Cement Clinker 1,500 deg. C.	Cement Clinker 1,435 deg. C.	C_3S	Beta C_2S	C_3A	CaO
1	3.02 s	3.02 s	3.02 s			
2	2.955 w	2.950 w	2.940 w			
3	2.755 ssb	2.760 ssb	2.750 ssb	2.750 ssb		2.765 m
4	2.690 m	2.685 m			2.690 ss	
5	2.610 ss	2.600 ss	2.600 s	2.610 s		
6	2.435 w	2.440 ww		2.440 m		
7	2.395 w	2.390 sb		2.400 m		2.390 ss
8	2.320 m	2.315 m	2.320 m			
9	2.275 w	2.270 w		2.278 m		
10	2.180 ss	2.175 ss	2.178 s	2.182 s		
11	2.040 wwb	2.035 wwb		2.030 mb		
12	1.980 m	1.978 m	1.975 m	1.980 m		
13	1.932 m	1.932 m	1.932 m			
14	1.905 m	1.905 m		1.895 mb	1.905 s	
15	1.824 wb	1.830 wb	1.825 w	1.800 m		
16	1.763 s	1.765 s	1.762 s			
17		1.698 s				1.695 s
18	1.624 s	1.629 s	1.627 s			
19	1.554 m	1.557 m			1.555 ss	
20	1.545 mb	1.545 mb	1.542 mb			
21	1.490 s	1.490 s	1.487 s			
22	1.462 w	1.460 wb	1.458 w			1.445 m
23		1.392 w				1.385 m
24	1.347 ww	1.348 ww			1.346 m	
25	1.200 wb	1.201 wb	1.198 w			
26	1.159 wb	1.159 wb	1.162 wb			
27	1.133 wb	1.134 wb	1.132 wb			
28	1.092 wb	1.092 wb	1.090 wb			
29		1.077 ww				1.075 m

Many other examinations of a similar character indicate that the free CaO may be detected in cements when present to the extent of 2.5 per cent. Of 28 commercial cements examined, however, the lines of free CaO have not been observed in a single case. This is convincing evidence that free CaO does not occur generally in modern rotary kiln clinkers in amounts as high as 2.5 per cent, and confirms the evidence obtained by chemical and microscopical tests.

Limiting Amounts Required for Identification

In order to determine the effect on the X-ray pattern of varying proportions of compounds, mixtures were made of the pure compounds which have been found to occur in cement. Thus a series of mixtures was prepared which contained various proportions of $3CaO.SiO_2$ and $\beta 2CaO.SiO_2$, and the X-ray diffraction pattern obtained of each mixture. Other series in which $3CaO.Al_2O_3$, $4CaO.Al_2O_3.Fe_2O_3$ and MgO were added to the silicates were included. By a study of these films the minimum amount of each material which could be detected in the presence of the others was determined. Also an idea was obtained of the relative intensities of the lines. Thus in a mixture of 85 per cent $3CaO.SiO_2$ and 15 per cent $2CaO.SiO_2$, only the most intense lines of $2CaO.SiO_2$ appear whereas only the least intense lines of $3CaO.SiO_2$ disappear. This series furnished a standard to which the films of commercial cements could be compared.

An additional set of standard films was obtained from a series of laboratory cements prepared of various compositions from the pure components: CaO, Al_2O_3, SiO_2, Fe_2O_3 and MgO. It was felt that in mechanical mixtures of pure compounds, crystals are apt to be better developed than in sintered cement clinkers. In the latter, the crystals are very small and intimately mixed so that this series of burned mixtures of known composition should furnish a set of standard films that more closely resemble the conditions met under commercial conditions.

From these studies there was determined under the conditions of test, the minimum amount of one compound which could be detected in the presence of the other compounds of the mixture. These results may be summarized as follows:

It was found by the X-ray method that, in the laboratory burns, $\beta 2CaO.SiO_2$ could be identified definitely in the presence of $3CaO.SiO_2$ only when the amount of $\beta 2CaO.SiO_2$ reached 15 per cent. This is due to the circumstance that the more intense lines of $\beta 2CaO.SiO_2$, which are the ones to appear when small amounts of $\beta 2CaO.SiO_2$ are present, nearly or quite coincide with lines of $3CaO.SiO_2$. Only when this minimum amount of $\beta 2CaO.SiO_2$ is reached do the weaker lines of that compound appear whereby it may be identified and its presence confirmed. Under unfavorable conditions, e.g., poor crystallization, it is probable that greater amounts may be necessary for identification.

The amount of $3CaO.SiO_2$ which can be identified in the presence of $\beta 2CaO.SiO_2$, or in cement clinkers may be as low as 8 per cent.

Because of the high order of symmetry and relatively simple structure of the crystals of CaO, MgO and $3CaO.Al_2O_3$, most of the lines in the patterns of these compounds are intense and therefore appear when only small percentages of those compounds are present. In mixtures of compounds approaching portland cement clinker in composition, the minimum amount of MgO which could be detected was about 2.5 per cent; CaO about 2.5 per cent, and $3CaO.Al_2O_3$ about 6 per cent.

$4CaO.Al_2O_3.Fe_2O_3$, like $\beta 2CaO.SiO_2$, gives a diffraction pattern containing only a few intense lines. And in cement-like compositions these lines nearly or quite coincide with lines of the other compounds. Therefore, to identify this compound, especially in the presence of $3CaO.Al_2O_3$ or $\beta 2CaO.SiO_2$, the minimum amount required is about 10 per cent in mixtures of the pure compounds and about 15 per cent in cement clinker. The larger amount required in clinkers may be due to poorer crystal formation; the combination of some of the Fe_2O_3 or Al_2O_3 with alkalies or other minor constituents which cannot yet be evaluated in the calculations; or to the failure of some of the $4CaO.Al_2O_3.Fe_2O_3$ to crystallize. Thus Hansen has observed that the iron phase frequently remains as a glass in the presence of silicates. If $3CaO.Al_2O_3$ is absent, or present only in small amounts, the quantity of $4CaO.Al_2O_3.Fe_2O_3$ necessary for identification in clinkers is less than 15 per cent.

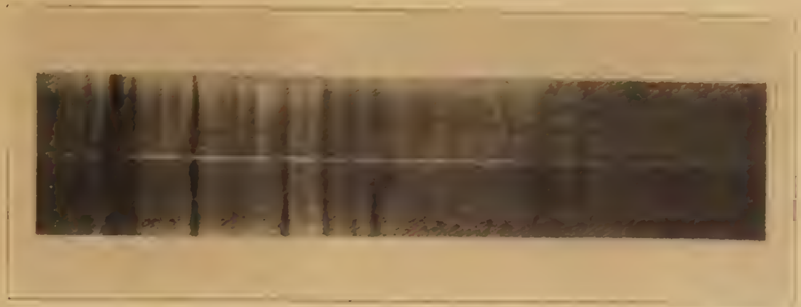

Figure 2. Upper: Mixture of 47 per cent $3CaO.SiO_2$, 47 per cent $\beta 2CaO.SiO_2$ and 6 per cent $3CaO.Al_2O_3$

Lower: Composition of same calculated content burned at 1525 deg. C.

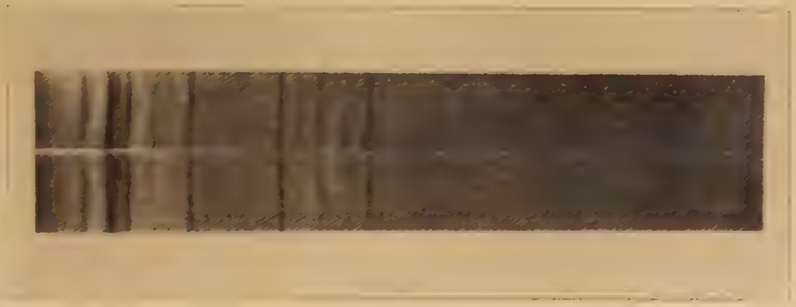

Figure 3. Upper: Clinker burned at 1435 deg. C. which contains 2.8 per cent free CaO

Lower: Clinker burned at 1500 deg. C. which contains 0.1 per cent free CaO

To summarize, in laboratory clinkers, the following amounts of crystalline phase must ordinarily be present in order to be susceptible of recognition by the X-ray diffraction method as employed in this study:

$3CaO.SiO_2$	8	per cent
$\beta 2CaO.SiO_2$	15	" "
$3CaO.Al_2O_3$	6	" "
$4CaO.Al_2O_3.FeO_3$	15	" "
MgO	2.5	" "
CaO	2.5	" "

Examination of Commercial Cement Clinkers

Twenty-eight commercial clinkers were examined by the X-ray diffraction method in the attempt definitely to identify the compounds present in them and to correlate the results obtained by X-ray examination with the composition as calculated from chemical analyses. These clinkers represent a variety of types of raw material and methods of manufacture, both domestic and foreign.

Table VIII gives the chemical analyses of three of these commercial clinkers together with the compounds present as obtained by calculation.[13] It should be pointed out that the status of equilibrium is taken into consideration in the calculations by means of the value obtained for the free CaO content.

Table IX gives the interplanar spacings and relative intensities of the lines of the X-ray diffraction patterns of these clinkers together with corresponding data for the compounds to which the lines may be assigned. In the diffraction patterns of the pure compounds, the weakest lines are omitted since such lines do not appear when the concentrations of the compounds are of the order found to obtain in cements. Complete diffraction data on these compounds have been reported from this laboratory.[2]

TABLE VIII

Chemical Analyses and Calculated Compound Composition of Three Commercial Cement Clinkers

Chemical Analysis	Clinker No. 1	Clinker No. 2	Clinker No. 3
CaO	63.4	64.5	66.0
Al_2O_3	6.6	6.4	4.4
Fe_2O_3	2.6	2.4	5.1
MgO	4.1	3.1	0.6
MnO	0.06	0.03	
SiO_2	22.8	22.8	24.0
SO_3	0.2	0.2	0.0
Loss	0.1	0.5	----
Free CaO	0.0	0.4	0.0
Compound Composition			
$3CaO.SiO_2$	37	41	50
$2CaO.SiO_2$	38	35	31
$3CaO.Al_2O_3$	13	13	3
CaO	0	0.4	0
$4CaO.Al_2O_3.Fe_2O_3$	8	7	15
MgO	4.1	3.1	0.6
$CaSO_4$	0.3	0.3	0

An examination of the diffraction data shows that there can be identified in clinkers 1 and 2 compounds $3CaO.SiO_2$, $\beta 2CaO.SiO_2$, $3CaO.Al_2O_3$ and MgO. The compound $4CaO.Al_2O_3.Fe_2O_3$, present (by calculation) to the extent

TABLE IX

Interplanar Spacings of Diffraction Patterns of Three Commercial Clinkers Together with the Interplanar Spacings of the Lines of the Cement Compounds Which May Be Observed When Those Compounds Are Present in Amounts Approximating the Quantities Predicted in Portland Cement Clinker.

Line No.	Clinker No. 1	Clinker No. 2	Clinker No. 3	C_3S	Beta C_2S	C_3A	MgO	C_4AF
1	3.02 m	3.02 m	3.03 m	3.02 s				
2	2.940 w	2.945 ww	2.950 w	2.940 w				
3	2.755 ssb	2.750 ssb	2.760 ssb	2.750 ssb	2.750 ssb			2.760 m
4	2.680 w	2.680 w				2.690 ss		
5			2.645 w					2.640 ss
6	2.605 s	2.595 s	2.590 s	2.600 s	2.610 s			
7	2.435 w	2.430 w	2.435 w		2.440 m			
8	2.405 w	2.390 w	2.400 ww		2.400 m			
9	2.320 w	2.315 w	2.315 w	2.320 m				
10	2.275 w	2.275 w	2.275 w		2.278 m			
11	2.180 s	2.175 s	2.170 s	2.178 s	2.182 s			
12	2.100 m	2.100 w					2.100 ss*	
13			{2.045 w					2.045 m
14	2.035 wwb	2.035 wwb	}2.030 wwb		2.030 mb			
15	1.980 w	1.975 w	1.978 w	1.975 m	1.980 m			
16	1.895-1.935 w	1.890-1.935 w	1.924 mb	1.932 m	1.895 mb	1.905 s		1.930 s
17	1.824 ww	1.824 wwb	1.823 w	1.825 w	1.800 m			
18	1.760 s	1.761 s	1.763 s	1.762 s				
19	1.623 m	1.626 m	1.624 m	1.627 s				
20			1.577 w					1.578 m
21	1.530-1.560 w	1.540-1.560 w	1.540 mb	1.542 mb		1.555 ss		1.538 m
22	1.485 s	1.488 s	1.488 s	1.487 s			1.486 ss	
23	1.454 w	1.458 w	1.460 w	1.458 w		1.346 m		
24	1.345 ww	1.345 w						
25			1.318 ww					1.318 m
26			1.210 w					1.209 w
27	1.198 w	1.197 w	1.198 w	1.198 w				
28	1.160 wb	1.158 wb	1.159 wb	1.162 wb				
29	1.131 wb	1.132 wb	1.133 wb	1.132 wb				
30	1.092 wb	1.092 wb	1.090 wb	1.090 wb				

*A typographical error appeared in a previous publication in the *American Journal of Science*, 15 (1928), 225, in which the line 2.100 for MgO was incorrectly listed 2.01 M.

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[13] R. H. Bogue, *Ind. Eng. Chem.*, Analytical Edition 1 (1929), 192.

of 3 and 7 per cent respectively, was not definitely identified in those two clinkers.

In clinker No. 3, which contained (by calculation) 3 per cent of $3CaO.Al_2O_3$, 15 per cent of $4CaO.Al_2O_3.Fe_2O_3$ and 0.6 per cent of MgO, only the lines of $4CaO.Al_2O_3.Fe_2O_3$ were identified in the pattern in addition to those of $3CaO.SiO_2$ and $\beta 2CaO.SiO_2$. The low concentration of the $3CaO.Al_2O_3$ and MgO accounts for the absence of the lines of those compounds in the pattern.

These three clinkers were selected for detailed presentation because they are typical and represent rather widely varying compositions. Twenty-five other commercial cement clinkers were examined by this method. In all of them, without exception, $3CaO.SiO_2$ and $\beta 2CaO.SiO_2$ were identified. Furthermore, the patterns of those two compounds were always the most prominent, indicating that they are the most abundant constituents of normal cement clinker. One or more of the compounds $3CaO.Al_2O_3$, $4CaO.Al_2O_3.Fe_2O_3$ or MgO were identified in most of the clinkers, but not all of these latter compounds were identified in all clinkers. As previously pointed out, the X-ray method fails to indicate the compounds when they are present in amounts less than a certain minimum value. In no case, however, has any inconsistency been observed between the computed constitution, due consideration always being given to the free CaO, and the X-ray observations, although, to bring out the desired relationships, special exposures and developments have sometimes been necessary.

No one method of approach to the complicated problem of the constitution of portland cement may be regarded, of itself, as altogether conclusive. The separation of the compounds from a finely ground sample by methods based on differences in specific gravity probably cannot be made complete because of the intimate intergrowth of the crystal phases. Microscopical examinations are satisfactory when made on especially prepared laboratory clinkers, but the fine structure and intergrowth of the constituents of commercial clinkers make for difficulties in the interpretation of optical data when applied directly to the commercial material. Calculations based on the phase-rule interpretations of chemical analyses are open to the criticism that the exact state of the equilibrium which obtains and the effect of the minor-components are not known precisely. Of itself, the X-ray method also is inconclusive for it is not capable of detecting small amounts of a crystalline phase nor large amounts of an amorphous composition.

Taken together, however, the cogency of the data obtained by phase equilibria, chemical, microscopical and X-ray methods becomes profoundly impressive. There is in no case a conflict in interpretation and, where one method fails, the other methods usually supply the information to complete the picture. It is especially noteworthy that the X-ray method can be applied directly to commercial clinker. The results obtained by it are not to as large an extent as in phase equilibria studies, dependent upon a scientific deduction following established laws. But the confirmation of those deductions by the X-ray method, as also by the microscopical method, leads to increased confidence in the findings.

The X-ray technique has not yet been developed to a degree where the method may be employed for the quantitative estimation of the compounds present.

Summary

The X-ray method has been applied in recent research to a study of the compounds which may occur in portland cement clinker. The present investigation is concerned with a number of subjects regarding the constitution of cement clinker and with the identification of the compounds that occur in the commercial material.

An examination of the composition $3CaO + SiO_2$ has shown that $3CaO.SiO_2$ exists and can be formed by the heating together, under the proper conditions, of a properly proportioned mixture of lime and silica. It is shown, furthermore, that CaO does not enter into solid solution with $2CaO.SiO_2$ in appreciable amounts, but that compositions ranging between $2CaO + SiO_2$ and $3CaO + SiO_2$, properly heated, contain at equilibrium a mixture of $3CaO.SiO_2$ and either γ or $\beta 2CaO.SiO_2$.

A study of the composition $8CaO + Al_2O_3 + 2SiO_2$ has shown that a compound of that composition does not exist in the system $CaO\text{-}Al_2O_3\text{-}SiO_2$ nor in portland cement. On the contrary, such a mixture properly heated, gives $3CaO.SiO_2$, $\beta 2CaO.SiO_2$ and $3CaO.Al_2O_3$ and, if equilibrium is not complete, a small amount of CaO.

A special examination of the system $3CaO.SiO_2\text{-}2CaO.SiO_2\text{-}3CaO.Al_2O_3$ has shown that solid solution does not occur between either of the above silicates and the aluminate in appreciable amounts. The mixtures at equilibrium contain only those three compounds.

Free CaO was not found in commercial cement clinkers by the X-ray method. A study of the identification of that compound indicates that a percentage of CaO of 2.5 could be recognized. Hence it is demonstrated that free CaO is not commonly present in commercial clinkers in amounts as high as 2.5 per cent.

The minimum amounts of the cement compounds that could be detected in controlled laboratory burns by the X-ray method, as used in this study, were as follows:

$3CaO.SiO_2$	8 per cent
$\beta 2CaO.SiO_2$	15 per cent
$3CaO.Al_2O_3$	6 per cent
$4CaO.Al_2O_3.Fe_2O_3$	15 per cent
MgO	2.5 per cent
CaO	2.5 per cent

The X-ray diffraction patterns of 28 commercial portland cement clinkers, representing many types of raw material and processes of manufacture, both domestic and foreign, were obtained. $3CaO.SiO_2$ and $\beta CaO.SiO_2$ were identified in each as unquestionably the most abundant constituents. $3CaO.Al_2O_3$, $4CaO.Al_2O_3.Fe_2O_3$ and MgO were identified, separately or together, in most of the clinkers but, in many of them, the patterns of one or two of these latter compounds were not observed.

The results obtained in this investigation by X-ray methods are in agreement with those obtained by phase equilibria, chemical and microscopical methods. Each supplements and confirms the other. Taken together, the cogency of their findings becomes convincing. These findings define the major constitution of portland cement clinker. They indicate that the most abundant constituents are tricalcium silicate and beta dicalcium silicate; that there are normally present, in addition, tricalcium aluminate, tetracalcium alumino ferrite and magnesia; and that free CaO is not normally present in amounts as great as 2.5 per cent.

1930 "Most Successful Year" for South Dakota State Plant

What operating officials term the most successful year in the history of South Dakota state cement plant terminated with the close of 1930.

A total of 582,379 barrels of finished cement were manufactured during 1930, according to William F. Fowden, superintendent, compared with 528,866 barrels in 1929, or a gain of 53,513 barrels. Up to December 27, the date for which latest figures were available, about 556,790 barrels of cement had been shipped from the state-owned factory, a gain of about 15,549 barrels over shipments on the same date last year, said E. E. Hartley, sales manager.

Forty-three Plants Earn Trophies for 1930 Safety Records

A total of 43 American cement manufacturing plants completed the year 1930 with no lost-time or fatal accidents. According to the annual accident prevention report of the Portland Cement Association, accidents of all types were reduced in member plants by more than 28 per cent below 1929 figures, while production fell less than 5 per cent. Already ranking first among the 27 principal industries in point of rarity of accidents, the cement industry seems assured of its continued leadership.

Lost-time accidents during the year showed a drop of 27 per cent under the figures for 1929, while fatal accidents were decreased by nearly one-half—45 per cent. The number of plants operating for the year without a fatal or lost-time accident increased by 17 over the 1929 record figure of 26. Of the total of 43 such plants, 26 operated a calendar year for the first time without an accident.

Improvement Over Past

When, in 1924, the Portland Cement Association began awarding trophies to plants completing any one year without a disqualifying accident, but one was awarded. Two trophies were presented each year to successful plants in 1925 and 1926. The years 1927, 1928 and 1929 saw trophy presentations rise to 10, 17 and 26, respectively, indicating a consistent trend toward accident prevention within the industry. The 43 awards for 1930 make up 44 per cent of the total presentations for the seven years.

Of the 1930 safety trophy winners, two plants are entering their fifth year without a disqualifying accident, while six plants have a no-accident record of two years' standing. Three other plants, besides the 43 trophy winners, have perfect records but were disqualified because they failed to meet the minimum operation requirement.

The distinction of being the largest cement plant in the country ever to win the annual safety trophy offered by the association was achieved last year by the Pittsburgh plant of the Universal Atlas company. With more than 500 employees and with a producing capacity of nearly 20 million sacks of cement a year, this plant operated throughout 1930 without a lost-time accident.

"In addition to the perfect score for 1930, we did not have an accident in 1929 after September 3; our safety record is thus continuous for 484 days," according to E. D. Barry, now assistant operating manager and formerly superintendent.

R. L. Slocum is now superintendent of the Pittsburgh plant. J. R. Cline is assistant superintendent. These two are aided in safety work by E. H. Loveday.

WINNERS OF PORTLAND CEMENT ASSOCIATION SAFETY TROPHY FOR 1930

Position	Company	Plant	Days Clear to Jan. 1, 1931
1	*Lehigh	Iola, Kans.	1574
2	*Alpha	Ironton, Ohio	1484
3	*Medusa	Toledo, Ohio	1001
4	*Lehigh	Ormrod, Pa., No. 2	887
5	*International	Irvin (Spokane), Wash.	883
6	*Lehigh	Birmingham, Ala.	858
7	*Pacific	Redwood City, Calif.	765
8	*Great Lakes	Buffalo, N. Y.	742
9	*Canada	Port Colborne, Ont.	628
10	Nazareth	Nazareth, Pa.	624
11	*Lehigh	Mitchell, Ind.	575
12	Alpha	Birmingham, Ala.	556
13	Alpha	Cementon, N. Y.	555
14	Wabash	Stroh, Ind.	538
15	Vulcanite	Vulcanite, N. J., No. 2	536
16	Wellston	Superior, Ohio	534
17	*Lehigh	Sandt's Eddy, Pa.	529
18	Crescent	Wampum, Pa.	520
19	North American	Hagerstown, Md.	510
20	Petoskey	Petoskey, Mich.	506
21	North American	Howes Cave, N. Y.	501
22	Alpha	LaSalle, Ill.	499
23	Federal	Buffalo, N. Y.	489
24	Universal Atlas	Universal (Pittsburgh), Pa.	484
25	Medusa	York, Pa. (white plant)	475
26	Alpha	St. Louis, Mo.	474
27	Manitowoc	Manitowoc, Wis.	455
28	Penn-Dixie	Portland Point, N. Y.	450
29	*Lehigh	Fogelsville, Pa.	433
30	Medusa	Bay Bridge, Ohio	425
31	*Alpha	Manheim, W. Va.	418
32	Medusa	Dixon, Ill.	412
33	Diamond	Middle Branch, Ohio	405
34	*Canada	Fort Whyte, Man.	398
35	*Canada	Exshaw, Alta.	391
36	Penn-Dixie	Nazareth, Pa., No. 4	390
37	*San Antonio	San Antonio, Texas	386
38	Newaygo	Newaygo, Mich.	385
39	Trinity	Fort Worth, Texas	384
40	*Lehigh	New Castle, Pa., No. 3	384
41	Lone Star Texas	Houston, Texas	383
42	Cuban	Cayo Mason, Cuba	377
43	Lone Star Indiana	Greencastle, Ind.	369

Plants Which Operated Without Accident During Year But Were Ineligible for Trophy Award, Having Produced Clinker for an Aggregate of Less Than 6 Months

Position	Company	Plant	Days Clear to Jan. 1, 1931
1	Three Forks	Hanover, Mont.	618
2	Lehigh	Bath, Pa.	461
3	Pacific	San Juan Bautista, Calif.	413

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*Previous trophy winner.

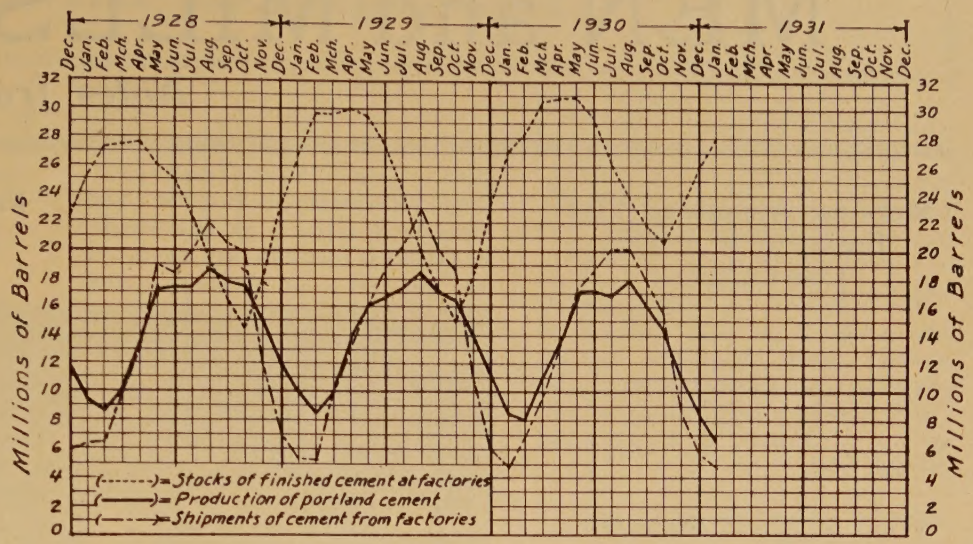
Cement Statistics for January

Low Production and Shipments Continue — Stocks Slightly Higher Than in 1930—Output at 30 Per Cent of Capacity

Relation of Production to Capacity

(Figures represent per cent)

	The Month	The Twelve Months
January, 1931	29.5	60.6
January, 1930	**38.8**	**65.5**
December, 1930	38.2	61.5
November, 1930	51.7	62.6
October, 1930	65.4	64.2



	1930	1931	Increase or Decrease, %
Production, January	**8,498,000**	6,581,000	—22.6
Shipments, January	**4,955,000**	4,687,000	—5.4
Stocks at end of Jan.	27,081,000	**27,777,000**	2.6

	1930	1931	Increase or Decrease, %
Total production for year	(Same as first item)		
Total shipments for year	(Same as second item)		
No. of plants reporting	165	165	0.0

Production, Shipments, and Stocks of Finished Portland Cement, by Districts, in January, 1930 and 1931, and Stocks in December, 1930

District	Production—January 1930	Production—January 1931	Shipments—January 1930	Shipments—January 1931	Stocks at end of month 1930	Stocks at end of month 1931	Stocks at end of December, 1930*
Eastern Pa., N. J., and Md.	**2,286,000**	1,617,000	**1,388,000**	1,084,000	**6,075,000**	5,546,000	5,014,000
New York and Maine	320,000	**420,000**	**249,000**	206,000	1,615,000	**1,988,000**	1,775,000
Ohio, Western Pa., and W. Va.	**727,000**	505,000	**472,000**	367,000	3,289,000	**3,710,000**	3,572,000
Michigan	**346,000**	45,000	**234,000**	220,000	2,509,000	**2,915,000**	3,090,000
Wis., Ill., Ind., and Ky.	**1,377,000**	804,000	327,000	**354,000**	3,926,000	**3,955,000**	3,505,000
Va., Tenn., Ala., Ga., Fla., and La.	**842,000**	646,000	**730,000**	679,000	1,753,000	**1,766,000**	1,799,000
Eastern Mo., Ia., Minn., and S. Dak.	758,000	**854,000**	214,000	**288,000**	**3,140,000**	3,069,000	2,503,000
W. Mo., Nebr., Kans., Okla., and Ark.	**701,000**	450,000	271,000	**321,000**	1,889,000	**2,218,000**	2,089,000
Texas	321,000	**322,000**	317,000	**340,000**	**817,000**	782,000	799,000
Colo., Mont., Utah, Wyo., and Idaho	....	**123,000**	42,000	**50,000**	**415,000**	410,000	337,000
California	**718,000**	624,000	640,000	**643,000**	**1,168,000**	858,000	876,000
Oregon and Washington	102,000	**171,000**	71,000	**135,000**	485,000	**560,000**	524,000
	8,498,000	6,581,000	**4,955,000**	4,687,000	27,081,000	**27,777,000**	25,883,000

Production, Shipments, and Stocks of Finished Portland Cement, by Months, in 1930 and 1931

Month	—Production— 1930	—Production— 1931	—Shipments— 1930	—Shipments— 1931	Stocks at end of month 1930	Stocks at end of month 1931
January	**8,498,000**	6,581,000	**4,955,000**	4,687,000	27,081,000	**27,777,000**
February	8,162,000	....	7,012,000	....	28,249,000	....
March	11,225,000	....	8,826,000	....	30,648,000	....
April	13,521,000	....	13,340,000	....	30,867,000	....
May	17,249,000	....	17,224,000	....	30,891,000	....
June	17,239,000	....	18,781,000	....	29,364,000	....
July	17,078,000	....	20,153,000	....	26,289,000	....
August	17,821,000	....	20,299,000	....	23,824,000	....
September	16,124,000	....	18,083,000	....	21,889,000	....
October	14,410,000	....	15,599,000	....	20,697,000	....
November	11,098,000	....	8,784,000	....	23,056,000	....
December	8,480,000	....	5,688,000	....	*25,883,000	....
	160,905,000	....	158,744,000	....	....	....

Black type indicates larger of two figures.

*Revised.

MEN and MILLS

Notes from the Field

Meisnest Appointed Vice-President of Pacific Coast Cement

Darwin Meisnest, until recently general sales manager of the Pacific Coast Cement Company, Seattle, Washington, was recently also appointed vice-president.

Only 35 years of age and connected with the firm for two years, Mr. Meisnest's rise has been rapid.

West Winfield Foremen's Club Elects New Officers

Members of the Foremen's club at the West Penn Cement Company plant, West Winfield, Pennsylvania, met recently and elected the following officers: Garrett Tyrrell, president; J. F. DeBerry, vice-president; H. R. Langston, secretary; R. A. Keasey, treasurer.

C. L. Wagner on Association Technical Committee

Vice-President C. L. Wagner, Superior Portland Cement, Incorporated, has been appointed on the Committee on Technical Problems of the Portland Cement Association.

Five-Pin Bowling Contest Under Way at Superior Plant

Early in February the Mill five-pin bowling team was leading the Superior League of the plant at Concrete, Washington, by a margin of one game over the office and laboratory.

Florida Portland Adds to Employes' Group Insurance

The Florida Portland Cement Company, Tampa, Fla., has taken another step toward the completion of its employes' group insurance program through the recent installation of more than $100,000 in accidental death and dismemberment insurance in combination with sick and accident benefits. The additional coverage is being underwritten by the Metropolitan Life Insurance Company.

In the main bloc of participating employes, individual benefits are based on salary, the accidental death and dismemberment insurance amounting to either $1,000 or $2,000, while the sick and accident benefits range from $5 to $40 a week. These weekly payments will be made when an employe is unable to work due to sickness from any cause, or injury received while off duty.

Besides creating an accidental death benefit, the dismemberment insurance will be paid in full to an employe suffering the accidental loss of any two members. One-half this amount will be paid for the accidental loss of one member.

When sick or injured and under the care of a physician, insured employes are offered the advantages of a visiting nurse service. In conjunction with this, the insurance company also maintains a health advisory bureau, whose functions include the regular distribution of pamphlets on life extension and hygiene.

Medusa Appoints Executives to New Positions

Henry Vanderwerp and David H. MacFarland have recently been appointed vice-presidents of the Medusa Portland Cement Company, and W. L. White has been appointed assistant general manager. O. C. Hubbard has been made district sales manager in charge of the Metropolitan district of Chicago.

Mr. Vanderwerp, since 1924 vice-president and general manager of the Manitowoc Portland Cement Company, is now located at the office in the Builders Building, at Chicago, as is Mr. Hubbard.

Mr. MacFarland and Mr. White are located at the company's main offices at Cleveland.

Mr. Vanderwerp joined the Newaygo Portland Cement Company in 1910, ultimately becoming sales and traffic manager of the Petoskey company. At present he holds the position of vice-president of the Manitowoc Portland Cement Company and the Cement Transit Company.

Mr. MacFarland was connected with the Atlas Portland Cement Company for some time in the sales and advertising department, until a year ago when he became assistant to the president of the Medusa company.

Mr. White joined Medusa seven years ago as superintendent of the Bay Bridge, Ohio, plant. He was soon appointed general superintendent over the four mills then operated by the company.

Mr. Hubbard was formerly district sales manager of the Newaygo company and has been in the cement business for 18 years.

Peaceful Life of Monroe, Michigan, Wins Former Canada Cement Head

Although Arthur C. Tagge will remain on the board of directors of the Canada Cement Company after retiring from the presidency, as announced recently, he will achieve the seldom-realized ambition of the successful man and live a quiet life in a small town. Mr. Tagge expects to make his home at Monroe, Michigan, in April.

He was born in Ann Arbor and is a graduate of the University of Michigan.

Georgia Cement and Products Offices to Atlanta

Removal of the Portland, Georgia, and the Birmingham, Alabama, offices of the Georgia Cement and Products Company to Atlanta, Georgia, was effected recently, according to an announcement by M. R. Park, manager in charge of the consolidated offices, who was formerly stationed at the Portland office.

Offices will be maintained at 820 Forsyth Building. The company's plant at Portland, near Rockmart, was built in 1920, and has a capacity of 500,000 barrels per year.

Petoskey Officers Re-elected for 1931

At a meeting of the board of directors of the Petoskey Portland Cement Company on January 30, the present officers were re-elected to their respective positions. J. B. John is president, Homer Sly, J. C. Buckbee and Herman Magnus, vice-presidents; John L. A. Galster, treasurer and manager, and Emory Nyman, secretary.

Philadelphia Office of Lawrence Portland Moves

Since January 1 the address of the Philadelphia office of the Lawrence Portland Cement Company, Inc., has been 225 South Fifteenth Street. On that date it removed from 4 South Fifteenth Street.

R. A. Pruden continues in charge as district manager.

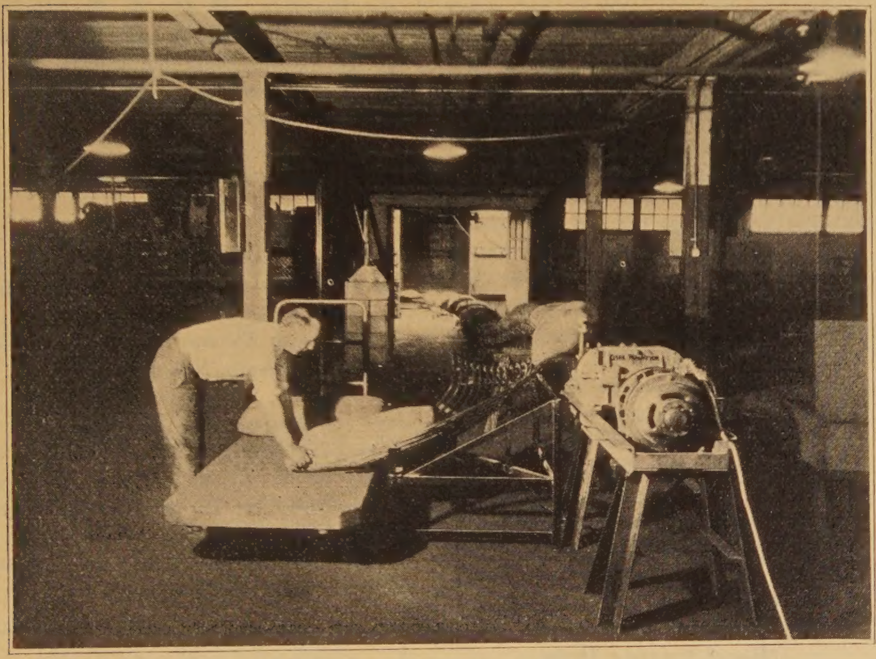
Dewey Salesmen Hold Annual Meeting at Davenport

The annual three-day meeting of salesmen of the Dewey Portland Cement Company was held at Davenport, Iowa, beginning January 15th.

Mill Equipment

Bag Handling Equipment to Reduce Costs

New car loading and unloading equipment which is said to make remarkable reductions in the cost of handling sacks consists of eight short sections added to the end of a standard Clark TwinVeyor. The TwinVeyor itself consists of a series of dual sections of spiral tubes turned toward each other by a power head.



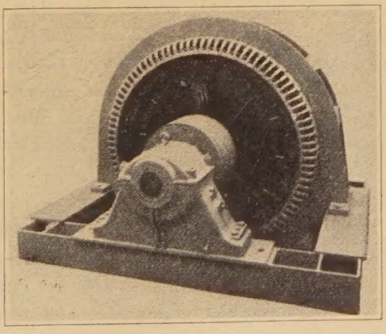
The operation of the loading assembly is as follows: The standard TwinVeyor line extends to the car door. The addition of four short dual sections extends the line into the car, makes the right angle turn to the right and, in operation, delivers the freight to the far end of the car, waist high. As the end of the car is filled, the end section of the TwinVeyor is removed. The line is successively shortened until one end of the car is completely loaded. Attachment of the four other sections of the car loading kit extends the line to the left hand end of the car and is similarly shortened as loading proceeds. With both ends loaded, the center section is loaded from the end of the TwinVeyor.

Transposing the right and left hand tubes in the assembly reverses the flow of material, making the unloading operation as easy as loading. The dual tube sections are easily handled. Attachment or removal of a section takes one minute, it is said.

The Clark Tructractor Company, Battle Creek, Michigan, manufactures the equipment.

New Type of Synchronous Motor to Marquette Plant

An announcement has just been made of a sale of a 1250 hp. Simplex synchronous motor and a magnetic control to the Marquette Cement Manufacturing Company.



This motor will drive a tube mill and will be installed at the plant at Cape Girardeau, Mo. This motor is a new idea in synchronous motors recently developed by Westinghouse for applications requiring high torque and low starting inrush. The motor's starting performance—torque and inrush—is very similar to that obtained on wound rotor induction motors. However, after the motor is synchronized, it operates as a standard salient pole synchronous motor with the inherent efficiency of this type of motor, the Westinghouse company states.

Amsco Welding Rod Now Available

Developed several years ago for the firm's own use in welding, the Amsco manganese steel welding rod was not generally sold by the American Manganese Steel Company, Chicago Heights, Illinois, until recently. Early in February announcement was made to the effect that it had been placed on the market.

The rod may be used for repairing or building up either manganese steel castings or other steels, and is stocked in A. S. & W. gauge No. 5, 36 in. long. The composition is covered by patent application. A manganese content of 13½ to 14 per cent and other important elements are said to give it a toughness and wear resistance equal to those of manganese steel.

For hard surfacing, the Amsco 459 welding rod has been tested in different kinds of field service, with considerable success, it is said.

INDUSTRIAL LITERATURE

Explosives Film

A new booklet entitled *"See Explosives via Du Pont Films"* has just been issued by the Motion Picture Bureau of *E. I. du Pont de Nemours & Company.* This booklet visualizes the part played by explosives in national industries, and states that the subjects for the films have been selected so as to give the audience a complete story from the manufacture and testing of explosives through to their various uses in industry and agriculture. Among the films described are Letting Dynamite Do It; The Story of Dynamite; and Dynamite in Quarry Work.

A page is devoted to the description of each film and contains as an illustration a scene taken from the picture described. Instructions relative to the use of the films are also given. Copies of the booklet are available on application to the Motion Picture Bureau, E. I. du Pont de Nemours & Company, Wilmington, Delaware.

About the Manufacturers of Equipment

INDUSTRIAL LITERATURE

Traylor General Catalog

General Catalog No. 4000, published by the *Traylor Engineering & Manufacturing Company*, Allentown, Pa., has just made its appearance. It is a 104-page, well prepared, high quality publication. It is designed to give the reader a brief but comprehensive idea of Traylor machinery, with sufficient data to enable him to determine its suitability.

Only salient features are pointed out, while tabular information is lengthy. Pages 75 to 92 are occupied by data on rotary kilns, coolers, dryers, wash and compartment mills, and feeders. Reference to numerous other kinds of cement plant machinery is made in earlier pages.

Laboratory Sieve

The *Weston* testing screen for coarse materials is described in a new 4-page folder published by the *Hendrick Manufacturing Company*, Carbondale, Pa.

A sample is run for two or three minutes and the sieves are then lifted for inspection and weighing. Each size of aggregate is in a separate sieve, allowing a visual inspection of each. The standard machine, it is stated, is made to hold four sieves and an extension shell.

Sprocket Stock

The 20,000 Link-Belt Caldwell sprockets always in stock are the theme of the new book, *No.* 1267, just issued by *Link-Belt Company* and *H. W. Caldwell & Son Co.*, their Chicago subsidiary.

This 24-page book, which is available gratis, is devoted to specifications of these sprocket wheels which are stocked in all standard sizes to fit popular chains, and are ready for immediate delivery; boring to fit shaft size being the only work necessary before shipping the same day.

Safety of Circuit Testers

Blasters do well to know that everything is in readiness before firing a shot. Is the electric blasting cap or electric squib in good condition? Will the blasting circuit function properly, or fail because of some faulty connection, broken wire or current leakage? And so to prevent misfires, shot firers make a practice of testing the approximate resistance of the wiring system before it is brought into actual use, states *Arthur La Motte* in a current issue of the *Du Pont Magazine.*

The question arises from time to time as to the safety of using a *Du Pont* circuit tester. On first thought it would seem rather risky to stand over a loaded bore hole and send a current of electricity through the electric blasting cap embedded in the dynamite. Yet the Du Pont circuit tester, properly assembled, has never caused an accident in firing a charge. Each instrument carries a plate which reads: "Danger. To use other than silver chloride cell for replacement is dangerous."

The silver chloride cell used in the Du Pont circuit tester is a special element characterized by long life and low current. In the size used, one cell without external resistance develops about .2 ampere and .9 volt, La Motte continues. As the minimum current required for firing an electric blasting cap is about .4 ampere and enough voltage to overcome the resistance of an electric blasting cap—about 1.5 volts for the shortest copper wire electric blasting cap in common use—it will be seen that there is a large margin of safety. Moreover, in an instrument properly assembled, the internal resistance of the circuit tester is 80 ohms, which gives a further factor of safety.

Diesel Engine Data

Diesel engine power costs are the subject of a 4-page booklet issued by the *Chicago Pneumatic Tool Company*, New York City. It comprises "actual cost data on a well designed and well operated modern Diesel power plant," presented in an article reprinted from a power engineering paper.

Dust Arrester Details

The Norblo cloth screen type dust arrester is described in *Bulletin* 100-1, prepared by the *Northern Blower Company*, Cleveland, Ohio. Construction, operation, and specifications are given and illustrations show different views in detail.

P.I.V. Gear Book

Link-Belt Company, Philadelphia, Pa., has just issued a new 16-page book descriptive of their recently announced *P.I.V. Gear*—and all-metal variable speed transmission.

Quarrying Under Mountain

"The Quarry Under Signal Mountain" is the title of a short article published in the January-February issue of the *Groundhog*, the *Marion Steam Shovel Company* house organ, published at Marion, Ohio.

The quarry is that worked by the Signal Mountain Portland Cement Company near Chattanooga, Tenn. Operating conditions and the part played by the shovel are summarized briefly.

Quarrying Discussion

A recent issue of *The Du Pont Explosives Service Bulletin* deals with *Safety in the Handling and Use of Explosives in Quarrying.* This is a general discussion of the subject, from the transfer of explosives to secondary blasting and the prevention of misfires.

Recording Instrument Publication

A new line of circular chart recording instruments, identified as Type A, including voltmeters and ammeters, is described in Leaflet 20512, recently published by the *Westinghouse Electric and Manufacturing Company*, Newark, New Jersey.

Induction Motors

Two new loose-leaf folders published recently by the *General Electric Company*, Schenectady, N. Y., describe totally enclosed, fan-cooled induction motors. One is *Type K* and the other is for Class I, Group D Hazardous Locations.

NOTES FROM THE FIELD

Link-Belt Sales Connection

E. C. Burton, vice-president of *Link-Belt Limited*, Toronto, announces the appointment of sales representatives in the prairie provinces.

In Manitoba and Saskatchewan, Link-Belt will be represented by Manitoba Bridge & Iron Works, Ltd., of Winnipeg. *Riverside Iron Works, Ltd.*, Calgary, will represent Link-Belt in southern Alberta.

Hercules Laboratories Near Completion

New experimental laboratories, costing more than half a million dollars, which will house the research facilities of the *Hercules Powder Company* at Wilmington, Del., are nearing completion. The main laboratory building and a number of smaller units have been finished and are awaiting installation of equipment.

The new location near Wilmington represents a closer contact of the company's research department and its main office, the laboratories being moved there from Kenvil, N. J. The new research laboratories will soon be formally opened.